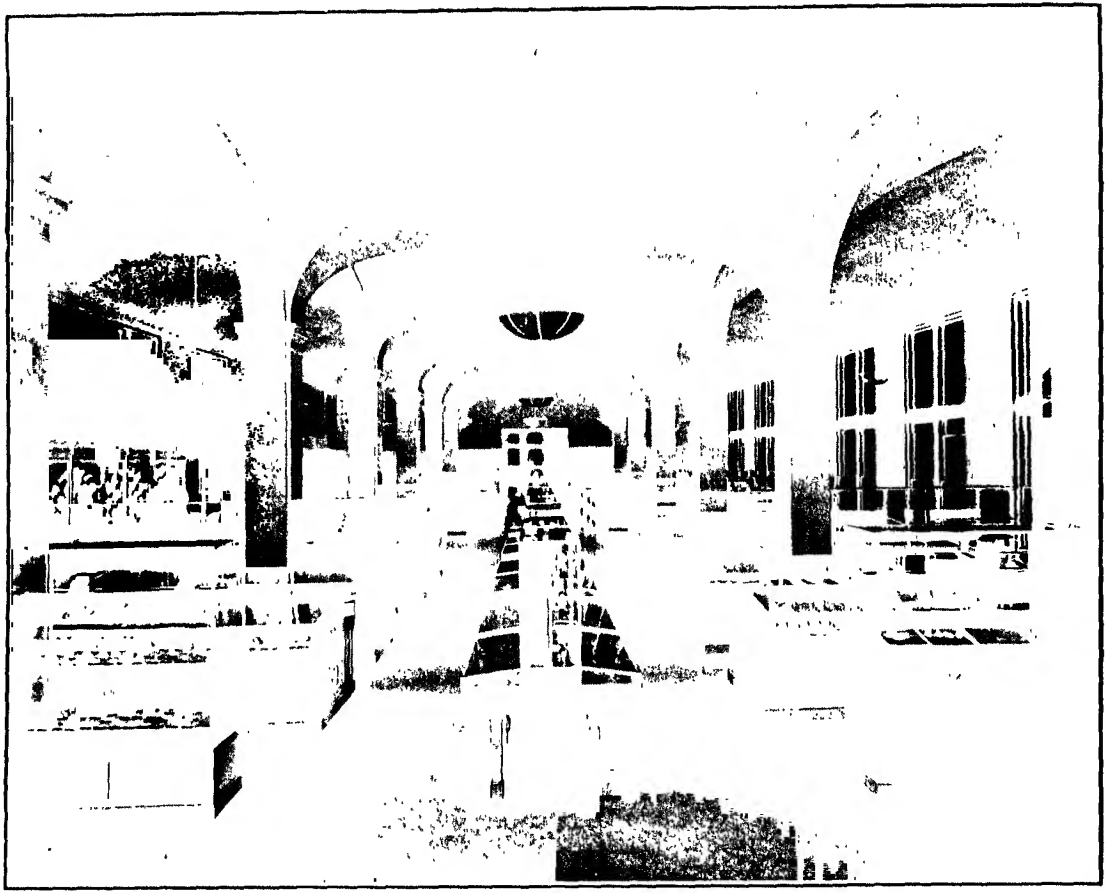
GETTING ACQUAINTED WITH MINERALS



Collections of Minerals and Gems of the American Museum of Natural History, New York City

GETTING ACQUAINTED WITH MINERALS

BY

GEORGE LETCHWORTH ENGLISH
Consulting Mineralogist

WITH 258 ILLUSTRATIONS

FIRST EDITION
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PREFACE

The aim of this book is to introduce the charming science of mineralogy in the simplest and most interesting manner possible, without sacrificing scientific accuracy.

It can be understood readily by a child of fourteen, yet its appeal is equally strong to the adult.

No previous knowledge of chemistry, physics or geometry is assumed, but every effort has been made to present, in an alluring manner, such facts and theories in these sciences as are essential to the understanding of the mineralogical topics treated.

Long years of contact with many beginners have persuaded the author that a worth while and continuing interest in minerals can be secured only by a guided study of carefully selected specimens. The guidance needed will be found in this book.

The study of crystals, usually regarded as too difficult for the beginner, is treated briefly, systematically, entertainingly and sufficient knowledge to awaken interest will be acquired without striking any snags. The difficulties are mentioned as goals to be reached, if desired, by more advanced study in later years.

While chemical examination and optical methods are the only means of positively identifying many minerals, yet the large majority who begin the study and collecting of minerals must learn about them without recourse to such aids. This book, therefore, stresses their physical properties, simple tests and careful observation.

As everyone is vitally interested in his own country, special emphasis is laid on the occurrence of minerals in the United States, whose mineral wealth greatly exceeds that of any other country.

GEORGE LETCHWORTH ENGLISH.

Rochester, New York,
December 1, 1934.

INTRODUCTION

For nearly half a century the name George Letchworth English has been almost a synonym for *mineral*. Mineralogists and crystallographers, professional and amateur, have relied largely on Mr. English for their supply of the rare, the beautiful and the useful products of the mineral world. And now that he has retired from his lifetime work of distributing minerals, he becomes a dispenser of information about them.

This book, in clear diction and with a wealth of illustration, speaks eloquently for itself, and its authorship is proof of its scientific accuracy. Mr. English has made this book for the beginner in mineral study; yet while simple, clear and nontechnical in description, it covers the science in more than an elementary way. The inquiring mind, once interested in the subject, will find here the guidance to expert knowledge, and as far as the book leads to popular interest in nature and science, it will be of great social value.

The boy, girl or adult, becoming interested in the book and the subject, will wish to know about the author and his work and qualifications Mr. English was born in 1864 in Philadelphia, where his father was a publisher of theological books, and all of his earlier years were passed in that city of scientific culture. From boyhood he was interested in nature and especially in minerals, and was one of a trio of young naturalists who explored the region, the others being Dr. George Howard Parker, Professor of Zoology at Harvard University, and the late Dr. Henry Skinner, Curator in Entomology in the Academy of Natural Sciences.

An enthusiastic collector of minerals from boyhood, young English pursued the study and developed it as a life work and has been a professional mineralogist since 1886. From 1886 to 1904 he was head of the firm of George L. English & Co., dealers in scientific minerals in Philadelphia and New York City. From 1904 to 1913 he was monazite expert for the National Light and Thorium Company, with headquarters at Shelby, North Carolina. From 1913 to 1921 he was Manager of the Department of Mineralogy and Petrography of Ward's Natural Science Establishment, Rochester, New York, and from 1921 to 1934 was Consulting Mineralogist for the same Establishment.

He was Associate Editor (for mineralogy) of the 1904 edition of the Encyclopedia Americana, contributing the article on Mineralogy and many others.

He is a life fellow of the Rochester Academy of Science and served

three terms as its President; a fellow and past Vice President of the Mineralogical Society of America; member of the Philadelphia Academy of Natural Sciences, the New York Mineralogical Club, the Mineralogical Society of Great Britain, La Société Française de Mineralogie, and other societies.

He has lectured on mineralogy in the New York City Board of Education course and before various scientific societies.

He has traveled extensively, collecting minerals in Europe, Africa, Australia, Brazil, Canada and the United States. He has probably collected and handled more scientific minerals than any other living mineralogist, and he is recognized as a world authority on their values.

He discovered the new minerals Penfieldite at Laurium, Greece; Graftonite near Grafton, New Hampshire; Pyroxmangite and Skemmatite near Iva, South Carolina. A rare calcium-potassium-aluminum phosphate was named Englishite in his honor by Professor E. S. Larsen of Harvard University.

As a long-time friend of Mr. English and an admirer of his scientific work and attainments, it is to me a pleasure to commend this fine book to students and collectors of minerals, with the hope that it may have wide distribution, increasing scientific interest in earth study.

Herman L. Fairchild

University of Rochester.

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PART I

Chapter 1

WHY STUDY MINERALS?

Those who study minerals are so enthusiastic over them, that there must be some reasons. What are they?

The study of minerals opens a new world. It leads, by pleasurable steps, into the great outdoors. It gives us the reasons for many striking features in the landscape. It shows us why the waves wear away one part of a rocky ledge more rapidly than another part. When we visit the Garden of the Gods, we understand its curious formations. The vivid colors of the Yellowstone, the Grand Canyon, and Zion Park, bring new pleasures to us because we attribute them to minerals. We understand, by a study of the properties of minerals, why the flints of Dover have such sharp edges, why the clays of Flanders are sticky, why graphite and soapstone feel so greasy, why diamond shows such a wealth of rainbow colors, why ice floats on water. The study of minerals, indeed, gives the answer to innumerable questions which are constantly being asked.

We visit the seashore, and, as the sands run through our fingers, we observe that the particles are not all colorless or white, but some are black, others yellow, green, or red, and our study of minerals enables us to identify them and, perhaps, see in them commercial values which otherwise would be overlooked.

We look around to find the source of these particles. Our quest leads us first to the adjoining cliffs, whose minerals fascinate us, though we fail to find in them all of the minerals which are in the sands, and, eventually we may learn that our colored particles originated back in the mountains hundreds of miles away.

We stop, as we motor past the roadside quarry, which we heretofore regarded as only a hole in the ground, and find in its debris many minerals, new to us, whose study profitably occupies our attention for many a pleasant evening. Some of our specimens are crystals. We want to know more about how they were formed and why they have assumed such regular shapes.

We begin the study of crystals. All around us are their beautiful

forms, even our table salt being revealed to us by a pocket lens as composed of multitudes of tiny crystals. We visit a mineralogical museum and are amazed to see the great variety of crystal forms in such a mineral as calcite. All through the museum we see different crystal forms, but, though there are thousands of them, we learn that they are all classified under only six systems, whose differences are easily understood. With what new pleasure we can study geometry when we see its forms illustrated wherever we turn in nature.

Recent discoveries in mineralogy, and its related science chemistry, are making the world over. New uses are constantly being found for minerals previously supposed to be worthless. Great deposits of minerals, heretofore unknown or regarded as rare, have been discovered and brought to the attention of chemists who have utilized them in the arts. Intensive study by advanced mineralogists in research laboratories has made possible many of the great inventions of our day. The beginner in mineral study need not be deterred in taking up mineralogy because he knows nothing of chemistry, for in a few hours, with the aid of this book, he will have learned all that is really essential to its elementary understanding. The further study of chemistry may be profitably pursued, if desired, and will be vastly more interesting when linked with a study of the composition of minerals.

The study of minerals acquaints us with one of the world's greatest sources of wealth, second only to agriculture. The search throughout the centuries for minerals of value, is full of romance. Even now there may be developing in the reader that irresistible urge to have a part in developing our country's mineral resources. Its great mines of metals and its quarries, or, it may be, its precious stones, will appeal to some as investments, to others as opportunities of applying better methods of recovery and separation. Familiarity with minerals is the foundation stone. Fortunes have been lost by a lack of knowledge of minerals; fortunes may be won and certainly a wealth of pleasure derived from the study of minerals.

Some knowledge of minerals is essential to culture. There are many references to them in literature, art is dependent upon them for many of its colors, science finds them one of its major bulwarks. Minerals are as necessary to life as food and enter in unnumbered ways into our every-day life, contributing immeasurably to our comfort and happiness and to the progress of the world. Many questions will arise in studying minerals to which answers will not be found in any textbook; thus you will be led to much delightful reading and research and many stimulating conferences with others who are already interested in minerals.

Begin the study of minerals with the conviction that you have chosen the most interesting and worth-while of all the sciences and that every specimen you acquire must contribute something to your knowledge of mineralogy. Seek them wherever you go, for they are all around you; learn to identify them by sight, to know their composition and crystal forms, their physical characteristics, how and where they occur. Learn about the great mineralogists of the past and present, about the many uses to which every inventor of note has put minerals, about the great collections both public and private, visit as many collections as possible, make the acquaintance of other mineral collectors, meet with them, hike with them and see how well minerals repay the time you spend on them. You will soon realize that mineral collecting can be much more than a delightful hobby and that the study of minerals affords you even greater pleasure.

Chapter 2

HOW TO COLLECT MINERALS

Before you start out either to collect or to study minerals, make up your mind that you are not going to be a quitter. It is foolish to begin and in a short time drop it. You would better not begin at all. Mineral collecting and mineral study are too delightful to fall into the hands of anyone who will not treat them right. Throw all of your enthusiasm into both collecting and studying and they will soon justify any expenditure of time and money you may be able to make upon them.

A collection of minerals of your own is essential to anyone who wants to enjoy them fully or who wishes to derive the greatest possible benefit from their study. This personal collection may be a very inexpensive one, or it may cost many thousands of dollars. Many persons derive greater pleasure from the minerals they find themselves and which cost them nothing, than is obtained by others who have spent lavishly for the purchase of superlatively fine specimens. This is largely because the wealthy buyer rarely takes time to study his specimens. It is not so much what minerals we have, as what we do with them, that determines our enjoyment of them and their practical value to us.

The author believes that before starting out on a collecting trip it is better to gain some little knowledge of minerals in general through study of their physical properties. This can be accomplished by the aid of this book and the purchase of inexpensive minerals, from time to time, as the study proceeds. Suggestions as to just what to buy will be found in the next chapter. If this preliminary study of minerals is begun in the autumn or winter, there will be plenty of time to complete it by the time good spring collecting days arrive.

Another most desirable preliminary to field collecting is a visit, or, still better, many visits to a good public mineral collection, such as that of the American Museum of Natural History in New York City, figure 1,

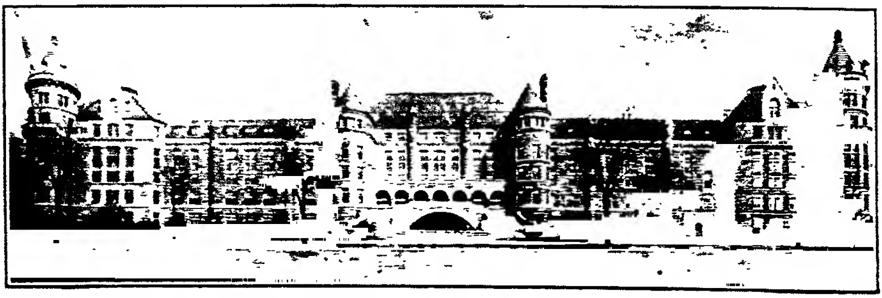


Figure 1. American Museum of Natural History, New York City

the Field Museum of Natural History in Chicago, the Harvard University Mineralogical Museum in Cambridge, or the U. S. National Museum in Washington. There are many other excellent collections in San Francisco, Denver, Pittsburgh, Philadelphia, Princeton, New Haven, and numerous other cities.

You should begin by making a general survey of the collection, going all through it and noticing the most striking features of the specimens. You will probably find on the labels not only the name of the mineral (and the variety, if any), but also the chemical formula. After you have acquired the elementary knowledge which this book gives, this formula will tell you of what constituents the mineral is made and later you will often come back to the museum and enjoy studying these chemical formulas. One of the first things you should do is to see the curator of the collection, tell him of your desire to become not only a collector, but also a student of minerals, and ask him what nearby mineral localities there are and what you would be likely to find there. Make a list of the minerals, then look them up in the museum's collection and familiarize yourself with their appearance.

If you cannot visit a public museum and do not know of any other collection which you can visit, ask a teacher of general science to direct you to some exposures of minerals in your neighborhood, or else start out and find one for yourself. There is an immense satisfaction about personally finding specimens, seeing how they occur and taking possession of them. You will be tempted to take home as many specimens as you can carry. It is better, however, to select your specimens carefully and consider at the start where you are going to put them and what you will do with them.

Let us assume that you visit a feldspar quarry. You will find there an abundance of very attractive specimens. If possible, trim up one fine specimen to about 2 x 3 inches, or if you have plenty of room, 3 x 4 inches. This will be for your permanent collection. Then collect from six to twelve small specimens which clearly show all of the points of interest you detect in the mineral and use these for study and testing. If you want to collect a few first-class specimens to exchange with other collectors, it may not be amiss to do so, but do not carry off a great load of specimens if they are going to fill all of your available storage space.

FIELD EQUIPMENT NEEDED

Whenever you go into the field collecting you will need a *good steel hammer.* Consult other mineral collectors, or the curator of a mineralogical museum before you buy one. Experienced collectors generally

agree that the best hammers are made of a tough steel, weigh about twenty ounces, are japanned to prevent rusting and have a square head with cutting edge at right angles to the handle, which should be of straight second-growth hickory. In one excellent type, figure 2, the

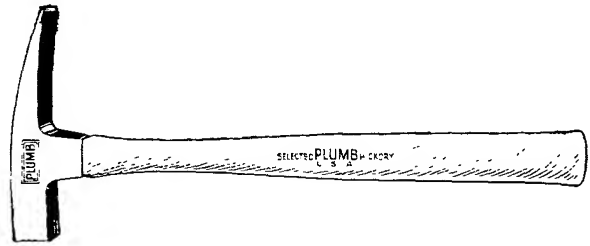


Figure 2. Mineral Hammer

head is securely fastened to the handle by a screw wedge. Such a hammer is necessarily costly, $2.50, but if you buy a cheap hammer, you will soon find that it is a poor investment.

A knapsack or some kind of a *collecting bag* to carry your specimens home is also desirable, though almost any kind of cheap sack can be used if it is necessary to economize. The most durable type is a leather bag about 12 x 12 x 4 inches, with a flap over the top and a strap and buckle to fasten it. A strong canvas bag, figure 3, is lighter and quite

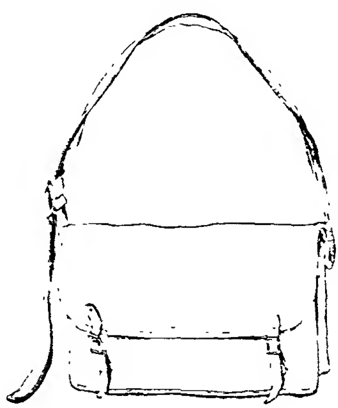


Figure 3. Collecting Bag

serviceable. It should be slung over the shoulder with a carrying strap preferably of strong leather about two inches wide, with a buckle and several holes so as to adjust it to the best length. Women often use shopping bags or large handbags.

A cold *chisel,* figure 4, is sometimes needed, but scarcely often enough to make it worth while to carry it, unless you are going to collect fine specimens.

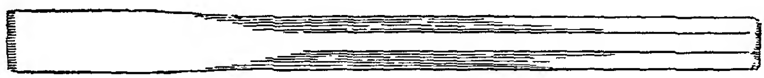
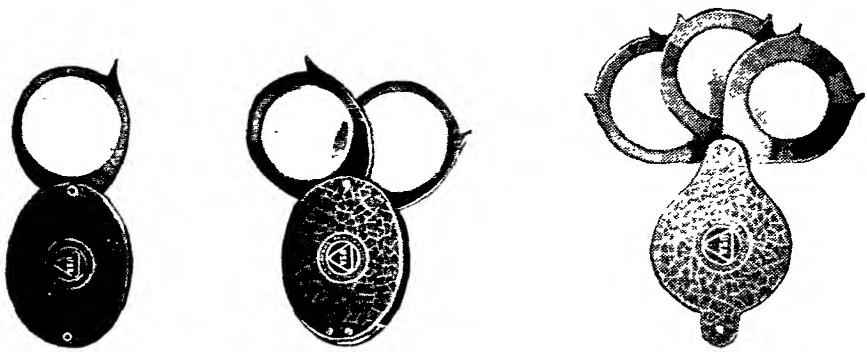


Figure 4. Cold Chisel

A small supply of *newspapers* and some *tissue paper* for wrapping specimens are essential if you expect to keep them from rubbing one another.

Always have a *pocket magnifier or lens,* with you wherever you are. You will have constant need for it. In this instance the most costly lenses ($7.50) are not at all necessary. You can get good enough magnifiers in folding, vulcanite mountings, figures 5, 6, 7, for $1.00 to $2.00.



Figures 5, 6, 7. Pocket Magnifiers

A *knife* often comes in handy, especially for testing hardness. If you collect from more than one locality in a day, it is a fine plan to number your specimens in the field and record them in a small *note book,* so that you can correctly label them when you reach home, for every specimen worth keeping should be labeled with its name and locality. An excellent way to number in the field is to prepare in advance a set of *numbers typewritten on adhesive tape* fastened for convenient preparation and carrying on tracing linen. These should be cut into strips about 5½ inches in length, figure 8, and carried in an envelope. You can cut them apart as you need them, with *a pair of scissors* which you should have in your bag, pull them loose from the linen and you will find that they will adhere tightly to almost any kind of a specimen simply by pressing the adhesive surface to the specimen.

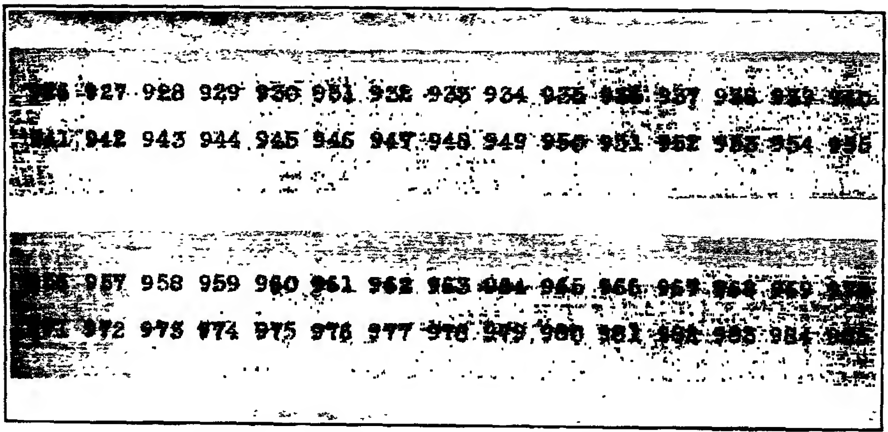


Figure 8. Numbers Typewritten on Adhesive Tape

STORING YOUR SPECIMENS

It is very important to have a good place to keep your specimens. It is probable that more collectors have stopped collecting because of lack of room than for any other cause. A *cabinet of drawers,* figure 9, filled with pasteboard trays, in which you can carefully preserve and classify your specimens is the ideal way to keep them. If you cannot afford this at the start, you can buy the drawers separately, one at a time, and eventually secure the whole cabinet. If this is not feasible, try to find

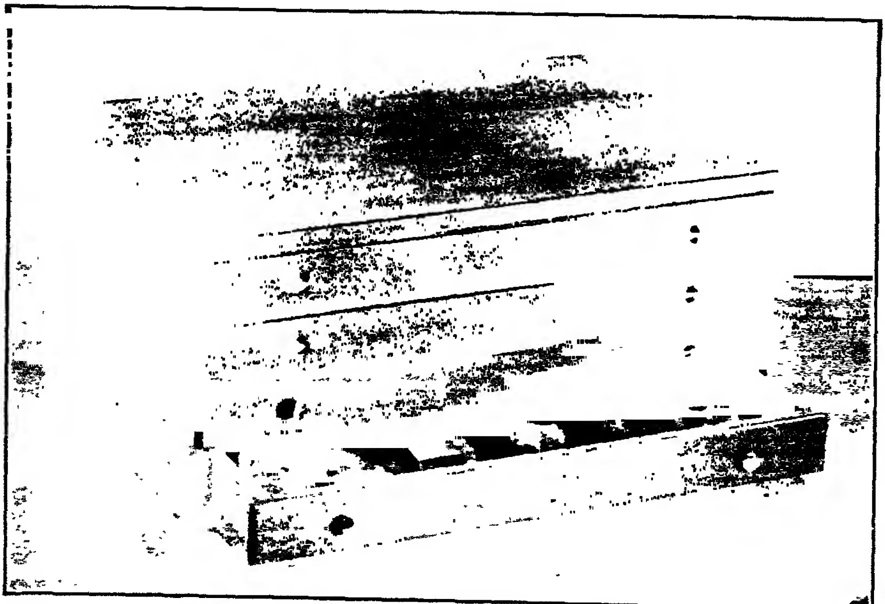


Figure 9. Cabinet of Drawers for Storing Minerals

several shallow boxes of the same size, preferably about 15 to 18 inches wide and a third longer. These will hold a good many specimens and some cheap partitioning such as is used in egg crates, may be used temporarily to separate your specimens. Cigar boxes sometimes are good temporary containers.

If you do not secure a cabinet of drawers, nor want to keep your specimens, for the time being, in boxes, maybe you can find room for them in a bureau, a spool case, on bookshelves, or in a china closet. Plan, sooner or later, to get a good case of drawers.

WHERE TO FIND SPECIMENS

Where will you find specimens? That depends upon where you live. If you live in a large city, very likely you will find *excavations* like that shown in figure 10, where you will find specimens. In general, the best

Figure 10. Excavation on Riverside Drive, New York City; Courtesy of J. G. Manchester

places are mines, quarries, railway cuts, excavations of any kind, exposed rock masses, boulders, and the base of cliffs. There are many localities in which no work has been done that yield excellent results. If there happens to be a monument works near you, it is probable that you will be able to secure chips of marble and granite there. If you live near a smelter, and can gain permission to collect there, you may secure some very interesting material. The *dumps of mines*, figure 11,

Figure 11. Mine Dump, Somerville, New Jersey; Courtesy of J. G. Manchester

and quarries are usually rich fields for collectors. It may be, however, that you live near the seashore in a flat country where there are no exposures of minerals or rocks. If so, you can probably find much of interest in the sands, as many minerals occurring in the back country are washed down by the rivers and deposited along the seashore.

A Warning. Do not begin your study of minerals with a piece of granite. Many teachers have attempted to interest their pupils in minerals by trying to point out the various minerals in granite. It is one of the favorite methods of beginning, but the author believes many pupils lose their interest in minerals because in commercial granites their component minerals are usually present in very small particles and it is simply impossible for a student to distinctly see and test the properties of these minerals. If, however, you first secure thoroughly typical specimens of quartz, feldspar, and mica, and learn their characteristics, you will be able to recognize these minerals in the granite rock.

On the other hand, a very coarse granite, or pegmatite, in which the several minerals are present in large, pure masses, may be an ideal specimen with which to begin your studies. Pegmatite often contains other minerals about which you will find it worth while to learn and you may secure some fine specimens by visiting the *waste piles of a quarry,* figure 12, where pegmatite is plentiful. Do not be discouraged if you find but little on your first visit, for there are many quarries

and mines which yield no good specimens for a time and then suddenly produce a wealth of splendid material.

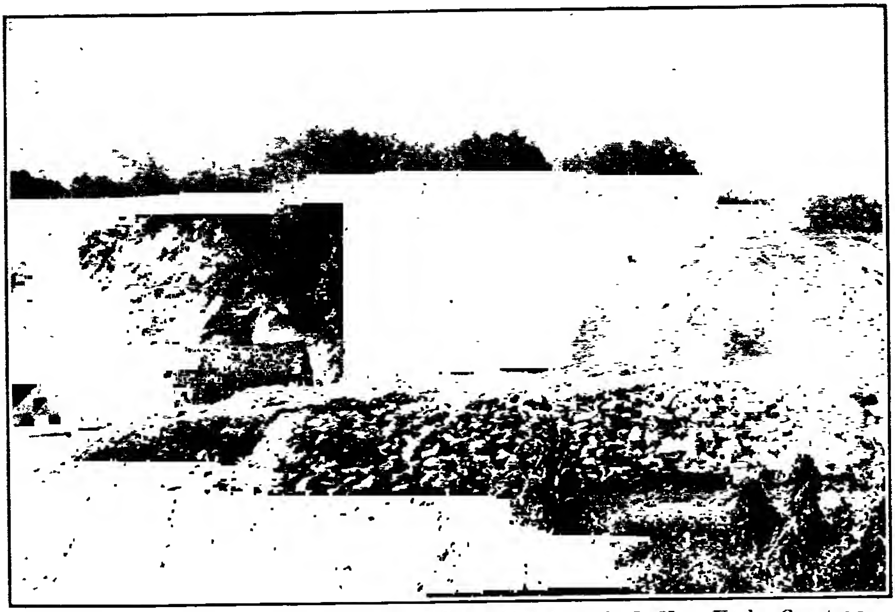


Figure 12. Waste Pile at Kinkel Feldspar Quarry, Bedford, New York; Courtesy of J. G. Manchester

MINERAL CLUBS

Comparing notes with other collectors is a fine way to get information and to give it. If there is a mineral club in your town, be sure to join it; if there is not, try to form one. Mineralogical clubs and societies are found all over the country and their number is rapidly increasing. Many of them have large membership and enthusiastic meetings. One mineral club in a western city, in a few months' time, attained a membership of over one hundred, with about 2000 junior members, some two hundred of whom formed collections of minerals and submitted them in a competitive exhibition. One of the best aids in learning about minerals is preparing papers on them for your club. To be truly successful such a club must have an efficient and enthusiastic leader and a definite program of activities. Club excursions to mineral localities give opportunity of exchanging ideas and learning much about minerals and their methods of occurrence.

MINERAL MAGAZINES

Be sure to subscribe to at least one good magazine devoted to minerals. You can join the Rocks and Minerals Association and secure *Rocks and*

Minerals for two dollars per year sent to the Association at Peekskill, New York. It is a live, wide-awake, little monthly, full of suggestions and with many informative articles, accounts of meetings of clubs and societies and advertisements of dealers.

The Mineralogist, published monthly at 701 Couch Building, Portland, Oregon, at $2.00 a year, is an excellent magazine. It contains a list of about three dozen mineral societies, reports of their doings and many interesting articles. *Maine Minerals,* published quarterly at 15 Thompson St., Brunswick, Maine, is also interesting.

A more technical journal is the *American Mineralogist,* published by the George Banta Publishing Company, Menasha, Wisconsin, at $3.00 per year. It is the organ of the Mineralogical Society of America.

Show your collection to as many of your friends as possible, tell them of the pleasure collecting minerals gives you, of the wonderful beauties of color and form you have seen for the first time in studying minerals, of the interesting reading to which they have led you, of the delightful trips you have had and are planning to take, of the high-class friendships you have made, and you will grow more and more enthusiastic over mineral collecting and study.

Chapter 3

WHY BUY MINERALS AND WHICH ONES?

Mineral collecting is such a delightful hobby that thousands and thousands all over the country are riding it as never before, and are enjoying it immensely. See! There is a big mass of rock which has just been blasted out of the quarry-side. What is there in it? Four collectors are trying to name the minerals they have found, but cannot do so. Another comes along and instantly declares: "That clear, glassy *mineral is quartz, that flesh-colored mineral with smooth* surfaces at right angles to each other is feldspar, that shiny mineral in plates which can be split off so easily into thin sheets is mica." How did he know? Why did he enjoy collecting so much more than the group who were perplexed over their finds? Simply because he had prepared himself for the collecting by preliminary study of thoroughly characteristic specimens which he had bought.

Material which clearly illustrates the properties of minerals can not be picked up wherever you go, indeed in the large majority of mineral localities there are apt to be many specimens which show few distinct characters and often the most abundant material consists of mixtures of several minerals, or, it may be, their characteristics have been destroyed by weathering. A dealer who specializes in educational minerals can supply, at small expense, just the minerals you need for that study of minerals which should always precede field collecting.

It is wiser not to regard such minerals as a part of your permanent show collection, for you will need to scratch them and pound them and by other tests, which this book explains, find out all you can about them. Let them be your "working collection." It should be composed of small specimens whose selection you should leave largely to the dealer who knows what you need and whose stock includes material from the best localities all over the world, secured expressly for study.

It is rarely wise at the start to buy a large collection, even though you can afford it. Its very completeness tends to dampen enthusiasm for collecting, because its owner thinks that it includes all of the minerals he needs. Furthermore, he does not want to mar its completeness by removing a specimen and breaking it up to test it.

WHAT MINERALS SHOULD BE BOUGHT FIRST?

Undoubtedly the first seven minerals in the *scale of hardness*, figure 13 (see page 31). These should cost not over seventy cents, plus post-

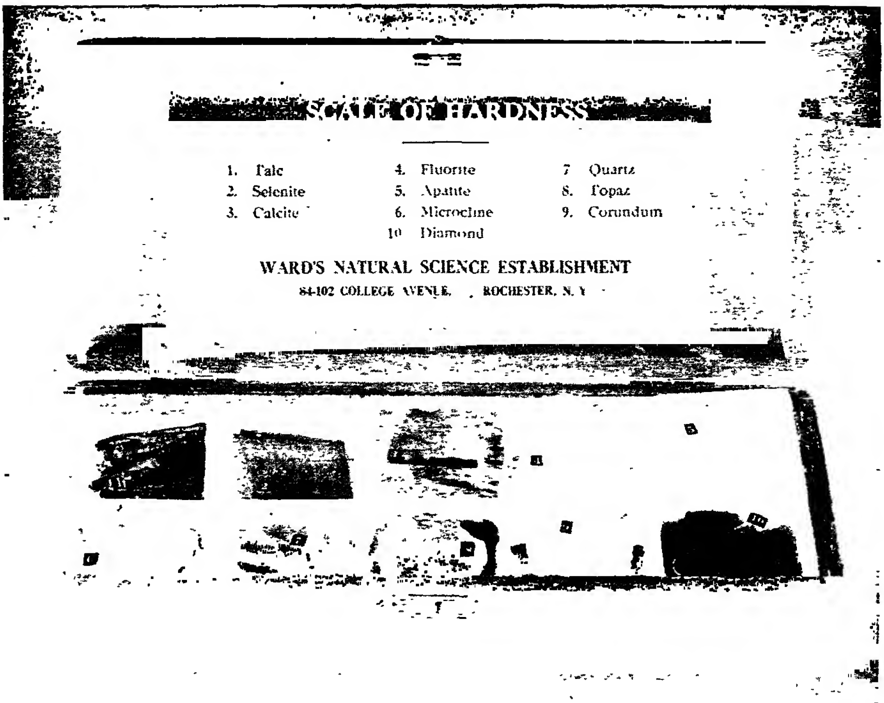


Figure 13. Scale of Hardness in Box

age. A box to hold them is a convenience, but if you need to economize, you would better dispense with it and put the savings into other specimens.

Let your next purchase be of specimens illustrating *tenacity.* You will know what to buy by reading Chapter 6. After you buy the specimens, study the chapter with their aid.

A little series of *natural crystals* will aid you to recognize in the field the forms about which you study in Chapters 7 to 12. You must not expect them to be of such ideal perfection as the figures shown in those chapters, for natural crystals never are perfect. Small crystals and the simpler forms will be satisfactory.

A series of specimens illustrating *cleavage and fracture,* as explained in Chapter 13, is a wise purchase, as you will then be able to recognize these important properties in any minerals you secure. If you belong to a mineral club, it would be fine for the club to spend an evening studying these two properties. If this is done, it would be better for the club to order one pound each of halite, fluorite, sphalerite, calcite, common feldspar, muscovite, selenite, amphibole and pyroxene. Be sure

to tell the dealer that these are wanted to break up to show cleavage and that the material must all show the cleavage well. A pound of obsidian might be added to show its fracture.

Specimens well illustrating *structure and form* are often difficult to secure and if every collector were to order them, the supplies of all dealers would be quickly exhausted. This very fact, however, will add to the incentive to secure them, for it is always a satisfaction to have something which other collectors want, but cannot get. If you find that you cannot buy just the specimens you want, do not abandon the effort to secure them, but study Chapters 14 and 15, with their illustrations, and look for the various types in your public museum. Some day you may find even better specimens of some of them than you have seen elsewhere.

It is very desirable for the student to familiarize himself thoroughly with the different kinds of *luster,* as this is such an important aid in determining minerals and it cannot be understood without actually seeing specimens. Look over the specimens you have already secured and you will find some of them which are excellent illustrations of certain kinds of luster, then write to a dealer who has a large stock and order specimens to illustrate the kinds of luster you lack. Most of them are inexpensive.

A series of specimens accurately showing the various *colors* of minerals will be difficult to obtain and more costly, but it will give much pleasure to any enthusiastic collector. Such a collection might well be bought by your club and be available for reference by its members.

A streak plate, to show essential colors, should be owned by every collector and is not costly. The little six-sided flooring tiles are an inexpensive substitute and answer fairly well.

Fluorescence is a property of minerals which is arousing widespread enthusiasm. Possibly no expenditure you could make would give you greater pleasure than the purchase of an "argon bulb" to show the marvelously beautiful colors which it produces in certain minerals. You will probably need to buy some of the minerals too, though it is quite probable that the fluorite in your scale of hardness will be most beautiful under the argon bulb. Chapter 17 will tell you more about what you need.

Buying Fine Specimens. This chapter has intentionally stressed the purchase of minerals for the working collection, for it is vastly more important that the beginner get a right start than that he be guided after he is no longer a beginner. It is reasonable to assume that if a collector follows the suggestions of this book and carefully studies its

chapters consecutively, he will reach definite conclusions as to the kind of specimens he wants to have in his permanent collection. Much depends too on the amount of money he can spend for minerals. Manifestly a superlatively fine collection, composed of the very best specimens obtainable, must necessarily be costly. Then, too, if a collector wants to have as large a number of species as possible, he will soon find that he will have to pay large prices for some species, while others will be absolutely unobtainable at any price. Choice crystallized specimens are usually considerably more expensive than massive specimens. If a collector spends a large amount of money in building up a fine collection, he should aim to secure specimens of larger average size than if he does not spend much. Superfine collections usually drift to the museums after the death of their owners, or possibly during their old age, and museums need large specimens because they are better adapted to display in open show cases than small ones. If the collector has it in mind that the ultimate destination of his collection is a public museum, he will do well to buy also a few superfine specimens of extra large sizes. It is highly important, however, that he bear in mind that the standard size for museum specimens in this country is 3 x 4 inches and if any specimens are larger than that size, they must be of superfine quality. A specimen 6 x 8 inches may be even less valuable than one 3 x 4 inches unless its quality is decidedly superior, for small collectors or those whose available space is limited, are not willing to buy specimens of such large sizes.

What constitutes a fine specimen? In general, and briefly, it is one which is shapely, fresh, clean, well crystallized (if occurring in crystals) with crystals attractively scattered over the rock, free from bruises and of considerable beauty, if the species is beautiful. In the case of rare species, or those not occurring in crystals, they should be fresh, shapely masses, either pure or attractively combined with the rock.

Where to buy. Inquire of the curator of any mineralogical museum, the professor of mineralogy in any college, ask other collectors, or read the advertisements in the mineralogical magazines.

Prices. Prices of minerals vary as much as prices of other commodities. Experience will soon show you that it pays to buy minerals of excellent quality, even though you may have to pay more for them. You will not, however, by any means always have to pay more for the best, for in many instances a large dealer, because of his ability to sell much more material, may pass on to the buyer the advantage of the lower prices he has paid for large quantities. He knows, too, just where to buy to the best advantage. You should never value your specimens

on the basis of prices asked at the localities. At some mines and quarries prices are ridiculously high, at others they are exceedingly low. You will find that the minerals for which you are asked high prices at localities can usually be bought from experienced dealers of international reputation at reasonable prices and that they do not overcharge you for the cheaper minerals. If you make all of your purchases from a reliable dealer, you will find that you are better off in the long run than if you try to save some money by purchasing from many different parties.

Do not delay starting *your permanent collection* until you have learned everything you can from your working collection, but buy one, two or three specimens at a time, selecting them with greatest care as the nucleus of a collection which you will be proud to own and show to your friends all of your life. If you adopt the plans suggested in this chapter, your interest in minerals will steadily increase.

Chapter 4

OF WHAT IS A MINERAL MADE?

The story of the make-up of a mineral is one of the most thriliing tales ever told. It concerns particles so minute that even the most powerful microscope falls far short of making them visible. It leads us into the fascinating field of chemical research, in which many of the world's greatest scientists have made revolutionary discoveries. This chapter is planned to give an inspiring glimpse into that field, leaving it to the earnest worker to pursue the subject as far as his time and inclination permit.

What are those tiny particles? The chemist calls them *atoms*. But how can particles so minute as to be absolutely invisible be of sufficient importance to make it worth while, in these busy days, to study about them? This you will soon understand.

One of the most startling claims ever advanced has recently been largely accepted by scientists. It is that *matter is nothing but electricity.* Well, suppose that is true, how does it have any connection with our question, "Of what is a mineral made?" Let us see!

The chemist has proved that everything in this world is composed of one or more of ninety-two simple substances called *elements*. Not only all minerals, but also all plants and animals are made of those elements. They are not all strangers to us, even though we may not have studied chemistry; soon we will recognize many of them as friends. Everyone is familiar with some of them, such as silver, iron, aluminum. Others are very rare and even many chemists have never seen them. Most of them are solids, a few are gases, two are liquids at ordinary temperatures. The astronomer and the physicist have co-operated with the chemist and proved that in all the great universe there are no other simple substances than these ninety-two elements.

It has been known for many years that the elements unite with each other to form *compounds,* but why some of them are very active in forming compounds and others do not enter into any combinations whatever remained a mystery until very recently. Even so great a chemist as Lord Kelvin, who passed away in 1907, after a long life devoted to chemical research, admitted that he did not understand why some elements are active and others inert. Today we all may understand it and find in the acquisition of the knowledge the keenest delight.

Chemists had long claimed that *the atom is the smallest part of an element which takes part in a chemical change.* It was believed that the atom was an absolutely unchangeable unit. But one day in 1898,

the chemists, Dr. and Madam Curie, discovered an element which they called *radium,* that simply overturned the theories about the atom. They showed that this element was constantly disintegrating, some of its atoms exploding and shooting off into space atoms of the gaseous element helium at the incredible initial velocity of about twelve thousand miles in a second. In addition to the helium, they proved that there were other "emanations" among which were negative particles of electricity. Scientists all over the world were much puzzled by these discoveries and set to work to account for them. Finally, they came to the conclusion that the electrical particles could come from no other source than inside the atoms of radium. Soon they evolved the *electron theory.*

The electron theory, which has revolutionized modern chemistry, can scarcely be more than touched upon here, but its study becomes more and more interesting the further it is pursued. It assumes, among other things, that atoms are made up solely of positive and negative particles of electricity; that in each atom there is a nucleus in which the positive particles, called *protons,* exceed the negative, called *electrons.* Outside the nucleus, there are exactly enough negative particles to balance the unsatisfied positive particles in the nucleus.

On page 22 is a list of all the known elements with the symbols which chemists and mineralogists use for brevity, instead of their names. They are arranged according to the electron theory, the numbers showing just how many electrons each element has outside of its nucleus; thus hydrogen has one, oxygen has eight and uranium, ninety-two.

Does this look like an unattractive list of names? It will become exceedingly interesting, as we learn more and more about the wonderful structure of the atoms. On page 23 there are diagrams, figures 14–21, showing the structure of the atoms of eight of the elements. The little dot in the center represents the nucleus. Around this nucleus the free electrons revolve, like planets around the sun. What an inspiring thought that all matter is made up of countless numbers of these tiny universes of atoms! Some little idea of their size may be gained by the statement that if 100,000,000 carbon atoms were strung out in a straight line they would measure less than five-eighths of an inch, yet there are many atoms even more minute!

Possibly we shall understand the relation of the elements to each other more quickly, if we make a single diagram, figure 22, embracing the first eighteen elements, designating each by its symbol and showing the number of its free electrons. We see that there are two electrons in the first ring, eight in the second and eight in the third. We shall soon understand the remarkable significance of the number and arrangement

of the electrons in the rings, for it gives us the clue to the question, "Why do some elements easily combine with others, while some are inactive?" This is the secret, withheld from Lord Kelvin, and it explains chemical activity and the formation of minerals.

ELEMENTS ARRANGED ACCORDING TO ELECTRON THEORY

No.	Name	Symbol
1.	Hydrogen	H
2.	Helium	He
3.	Lithium	Li
4.	Beryllium	Be
5.	Boron	B
6.	Carbon	C
7.	Nitrogen	N
8.	Oxygen	O
9.	Fluorine	F
10.	Neon	Ne
11.	Sodium	Na
12.	Magnesium	Mg
13.	Aluminum	Al
14.	Silicon	Si
15.	Phosphorus	P
16.	Sulphur	S
17.	Chlorine	Cl
18.	Argon	A
19.	Potassium	K
20.	Calcium	Ca
21.	Scandium	Sc
22.	Titanium	Ti
23.	Vanadium	V
24.	Chromium	Cr
25.	Manganese	Mn
26.	Iron	Fe
27.	Cobalt	Co
28.	Nickel	Ni
29.	Copper	Cu
30.	Zinc	Zn
31.	Gallium	Ga
32.	Germanium	Ge
33.	Arsenic	As
34.	Selenium	Se
35.	Bromine	Br
36.	Krypton	Kr
37.	Rubidium	Rb
38.	Strontium	Sr
39.	Yttrium	Y
40.	Zirconium	Zr
41.	Niobium	Nb
42.	Molybdenum	Mo
43.	Masurium	Ma
44.	Ruthenium	Ru
45.	Rhodium	Rh
46.	Palladium	Pd
47.	Silver	Ag
48.	Cadmium	Cd
49.	Indium	In
50.	Tin	Sn
51.	Antimony	Sb
52.	Tellurium	Te
53.	Iodine	I
54.	Xenon	Xe
55.	Caesium	Cs
56.	Barium	Ba
57.	Lanthanum	La
58.	Cerium	Ce
59.	Praseodymium	Pr
60.	Neodymium	Nd
61.	Illinium	Il
62.	Samarium	Sm
63.	Europium	Eu
64.	Gadolinium	Gd
65.	Terbium	Tb
66.	Dysprosium	Dy
67.	Holmium	Ho
68.	Erbium	Er
69.	Thulium	Tm
70.	Ytterbium	Yb
71.	Lutecium	Lu
72.	Hafnium	Hf
73.	Tantalum	Ta
74.	Tungsten	W
75.	Rhenium	Re
76.	Osmium	Os
77.	Iridium	Ir
78.	Platinum	Pt
79.	Gold	Au
80.	Mercury	Hg
81.	Thallium	Tl
82.	Lead	Pb
83.	Bismuth	Bi
84.	Polonium	Po
85.	———	
86.	Radon	Rn
87.	———	
88.	Radium	Ra
89.	Actinium	Ac
90.	Thorium	Th
91.	Protoactinium	Pa
92.	Uranium	U

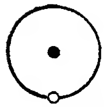


Figure 14. Hydrogen (H)

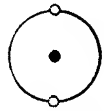


Figure 15. Helium (He)

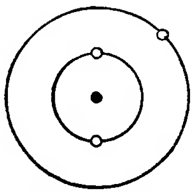


Figure 16. Lithium (Li)

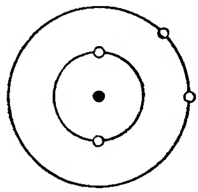


Figure 17. Beryllium (Be)

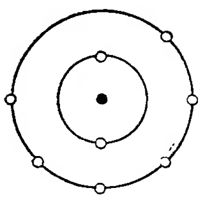


Figure 18. Oxygen (O)

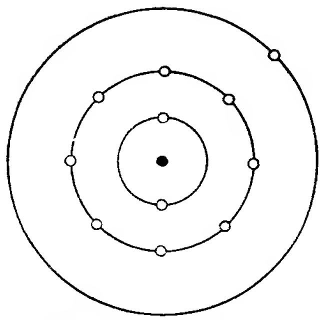


Figure 19. Sodium (Na)

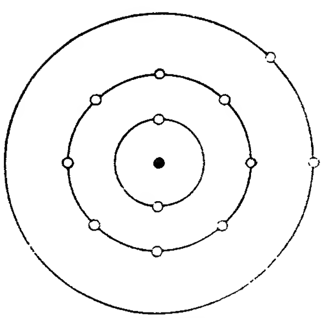


Figure 20. Magnesium (Mg)

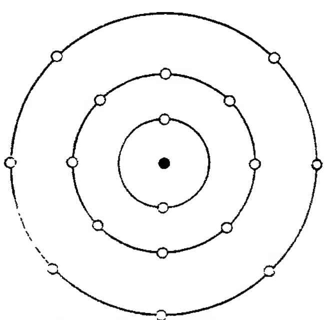


Figure 21. Chlorine (Cl)

Hydrogen (H) has one electron in the first ring; helium (He) has two; lithium (Li) has two in the first ring and one in the second ring; beryllium (Be) has two in the first ring and two in the second ring.

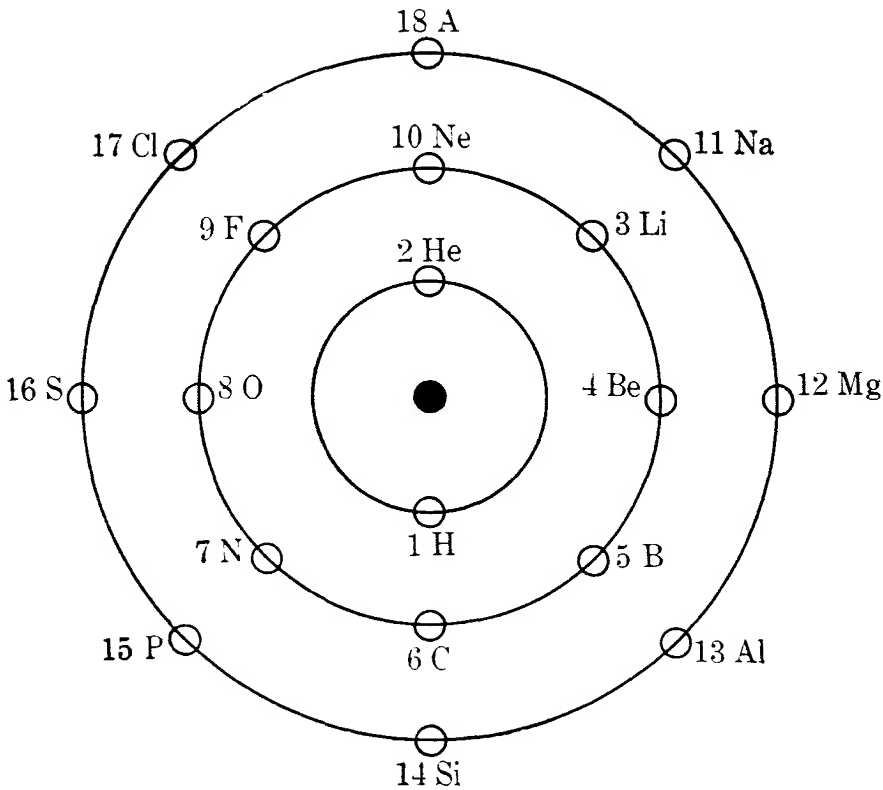


Figure 22. Free Electrons of First Eighteen Elements

Thus each of these elements has all of the electrons of the one just before it and one more.

When number 10, neon (Ne), is reached the second circle of eight is completed. It has been discovered that *every element whose outer ring of electrons is complete is always inert, or forms no compounds whatever.* Helium (He), in the first ring, neon (Ne) in the second and argon (A) in the third, have complete rings of electrons. All three of these elements are inert; all are gaseous elements in the earth's atmosphere.

Turning from the inert gases, what do we find of interest when we study the rings of electrons of some of the active elements? What thrilling adventures we would have if it were possible for us to watch the outer electrons of these elements, for by so doing we would see just how chemical compounds are formed. Let us look at the diagrams of the atoms of chlorine (Cl) and sodium (Na). We see that the sodium atom has only one electron in its third ring, whereas chlorine has seven,

instead of the complete number, eight. Chlorine holds tightly to its seven, while sodium's one electron in its outer ring is loosely held. The result is that sodium lends its electron to the chlorine atom, thus completing its third ring. The transfer is not so easy as it might appear, for the electrical balance of each atom is upset. Recall that we learned that the electrons, or negative particles, in the rings outside of the nucleus were just balanced by an excess of protons, or positive particles, inside the nucleus. When, therefore, the sodium atom gives up one electron, the part that remains is no longer neutral, but becomes positively charged. The acquisition of an electron by the chlorine atom causes it to become negatively charged. Bodies with unlike electrical charges attract each other, hence the negative chlorine and the positive sodium unite to form a *"molecule"* of sodium chloride, NaCl. This is a *chemical compound,* entirely different in its properties from its constituent elements, for sodium is a soft, silvery metal and chlorine is a green, poisonous gas, yet their compound is our ordinary table salt. What a wonderful transformation!

We have just seen a good illustration of certain very remarkable facts, *First,* that it is a general rule that *an element with only one or two electrons in its outer ring, readily parts with such electrons, while one whose outer ring is nearly complete readily takes on enough electrons to complete its ring. Second,* that *an element which has only a few electrons in its outer ring is a metal, while one whose outer ring is nearly complete is a non-metal.*

Let us look again at our diagram of the first eighteen elements and notice number 9, fluorine (F). Like number 17, chlorine (Cl), it lacks one electron to complete its outer circle; it is, therefore, an active element, seeking to combine with another which can spare it a single electron. Number 3, lithium (Li), has one to spare, and chemists know that such a compound, lithium fluoride (LiF), can be formed, though mineralogists have not yet discovered it as a mineral. Maybe you will be its discoverer! Fluorine, however, combines with other metals to form minerals, one of the most common of which is fluorite, calcium fluoride, whose acquaintance we shall soon make.

Haloids. Minerals which are simple compounds of chlorine, fluorine, bromine, or iodine with a metal are called *haloids,* because they are like halite or salt. We have now made the acquaintance of a small, but important class of minerals, whose most important members are halite and fluorite.

Sulphides. In the third ring of elements, number 16 is sulphur, symbol S. Note that as eighteen electrons are required altogether,

sulphur needs two more to complete the *ring*. Would you not conclude that it is an active non-metal? If you were to look over a complete list of all minerals, you would see that there are a great many compounds of sulphur with other elements, mostly metals, which is just what we would expect. These compounds are called *sulphides,* and they constitute one of the most important of all the classes of chemical compounds in the mineral world. *When we come to study individual minerals,* we shall be continually meeting the sulphides, especially among the ores of the metals, indeed in quite a number of instances they constitute the most important ores of the metals. This is true of galena, the commonest and most important lead ore; chalcopyrite, one of the most important copper ores; sphalerite, by far the most important zinc ore. Sulphur also has a strong affinity for oxygen, which has six electrons in the second ring and requires two more to complete its ring. When you study the electron theory further, you will better understand why one of the combinations of these two elements is itself very active in combining with the metals to form sulphates, about which we shall study shortly.

We have seen that the elements whose atoms have a complete ring of electrons in their outer circle, do not form chemical compounds with other elements. Does this suggest to you a reason why Uncle Sam uses helium in his dirigibles? It is not only because helium is so light a gas, but also because it will not burn, which is only another way of saying that it will not unite with oxygen.

But why is not hydrogen, which is only half as heavy as helium, preferred? We do not need to go anywhere for the answer except to the first ring of our diagram. There we see that it has but a single electron, and that this circle requires two to make it complete. Helium has the two and is inert; hydrogen is reaching out for another electron and is a tremendously active element. If you want to prove it, mix it with oxygen and put a lighted match to the mixture; but don't get too near, for there will certainly be an explosion. The oxygen and hydrogen rush together and unite to form the compound which we know as water!

Oxides. We shall study more about water at another time, but just at present let us fit it in one of the great classes of compounds, the *oxides, which are compounds of oxygen with any other single element.* We recall that the atom of oxygen has six electrons in its outer ring, and needs two more to complete the ring. This makes it a very active element, and it is constantly reaching out to others for the electrons it lacks. The result is that there are a great many oxides found in nature and many more which have been formed in the laboratory, which are not yet known in nature. Maybe you will discover one of them some day when you are in the field. There is always a chance of making

such a discovery, and such a possibility adds greatly to the zest of mineral collecting.

Another very common and exceedingly important member of the class of oxides is the oxide of silicon, which the chemist calls *silica*. Mineralogists, however, prefer giving minerals distinctive names, rather than adopt their chemical names, so they have called this compound, as usually found in nature, quartz. When we study this mineral, we shall see that it occurs in a greater variety of forms than any other mineral.

Among other important oxides are the common iron ores, hematite, magnetite, and limonite, all of which we shall soon meet. Then there are some beautiful gem minerals which are oxides, among them two of the most valuable of all gems, the gorgeous red ruby and the rich blue sapphire, both of which are varieties of the mineral corundum, the oxide of aluminum. The many-colored precious opal is an oxide; in this class also are cassiterite, the commonest of the tin ores, and bauxite, the most abundant aluminum ore. All of these, with the exception of opal, quartz, and water, are compounds of oxygen with one of the metals.

Carbonates. Another great class of compounds is the carbonates. The name at once suggests the presence of carbon. The carbon atom has four electrons in its outer ring, while eight are needed to complete this ring. It, consequently, can either give or take them on. We, therefore, find it combining with both the metals and the nonmetals. Its combination with oxygen is going on continually, day and night, in our own bodies, and, with every breath, we exhale this gaseous compound, known as carbon dioxide. It is present in the atmosphere and is the chief food of plants. In the mineral world it is found combined with many of the metallic elements, but most commonly with calcium in the mineral calcite. In many ways the study of calcite will afford us great pleasure, for its crystals are more varied than those of any other mineral. Its commonest occurrence is as the rock, limestone. A few of the other important mineral carbonates are dolomite, the calcium and magnesium carbonate; the iron carbonate, siderite; the lead carbonate, cerussite; the copper carbonates, malachite and azurite. All of the carbonates will fizz, if a fragment is heated in vinegar or any acid; and some of them, such as calcite, will fizz by merely dropping cold acid on them. This is because their carbon dioxide is driven off by the acid.

Silicates. There is a great class of minerals known as silicates, which consist of silicon and oxygen with one or more of the metallic elements. The silicates are among the most complex of all minerals, for they are the result of the interlocking of electrons of sometimes as many

as a dozen or more different elements, as in the mineral tourmaline Some day the analysis of such minerals in your own laboratory may become a delight to you, as it has been to many mineralogical chemists. While there are in this great class many rare species, the class also includes many of the rock-forming minerals, such as the feldspars, pyroxenes, amphiboles and micas. We shall find the study of the silicates most interesting.

Phosphates. One of the most active of the elements is phosphorus. Why? Refer to the diagram, figure 22, and you will find that it has five electrons in the third ring, and we have repeatedly seen that such an atom is constantly reaching out to the atoms of the metals to complete its ring of eight. It is not surprising, therefore, that we find many metals combining with it and oxygen to form the class of *phosphates.* We certainly ought to be familiar with phosphates, for we carry one of these around with us all of our lives, as our bones are chiefly calcium phosphate. Any farmer who uses fertilizers is familiar with "phosphate," of which the great chemical works prepare for him millions of tons annually. Its occurrence in nature is chiefly as the rock *phosphorite*, by many regarded as a variety of the mineral apatite, by others classified with collophanite.

Arsenates and Vanadates. Closely related to the phosphates are the *arsenates* and *vanadates*, which are compounds in which arsenic or vanadium takes the place of phosphorus. These compounds are usually grouped with the phosphates into one great class. There is no other group which includes so many minerals of beauty when viewed under the microscope. The most attractive of these are the many rare copper arsenates and the lead vanadates. A few years ago the latter were regarded almost as mineralogical curiosities; today they are important sources of vanadium used in automobile manufacture.

Sulphates. Another important class of compounds of oxygen is worthy of attention here, the *sulphates*. These are compounds of oxygen and sulphur with one or more of the metals. There is one very common sulphate among minerals, gypsum, which we are likely to meet over and over again and in many different forms. We shall study about it later. Another fairly abundant sulphate is barite or heavy spar, distinguished from other similar minerals by its great weight.

There are several other classes of oxygen compounds, but they are not very abundant. How marvelously this gas loses its identity in the host of compounds which it forms with other elements!

Formulas of Compounds. You have probably come to the conclusion already that some minerals are very complex chemical compounds.

and that if you had to record their composition in your notebook, it would take considerable space. Here again the chemist comes to the rescue with his labor-saving chemical formulas. These are made up of the symbols of the elements of which the compound is composed. If the elements are not combined in the proportion of one to one, a small figure is placed a little below the line, after the symbol of the element to show the number of its atoms in the compound. For example, water is composed of two atoms of hydrogen (H) combined with one atom of oxygen (O). Its formula is written H_2O. In corundum there are two atoms of aluminum (Al), combined with three of oxygen (O); its formula, therefore, is Al_2O_3. The use of these formulas saves much time.

It will not take long to learn the symbols of the elements which occur most commonly in minerals, and as soon as you have done so, you will find it very interesting to visit a large museum and examine the formulas which appear on the labels of the specimens, and in this way you will quickly learn their chemical composition and be able to answer for each mineral you see there the question at the head of this chapter, "Of what is a mineral made?"

We have seen that minerals are made of chemical elements and their compounds, but we have yet to learn that they must be formed in nature's laboratory. The conclusion is that a *mineral is any chemical element or compound occurring as a part of the Earth's crust.*

Now we have learned all of the chemistry we shall need for these preliminary studies of minerals, and we are ready in our next chapter to plunge into the study of their properties, which is one of the most delightful parts of the study of mineralogy.

Chapter 5

HARDNESS, OR THE MEANING OF A SCRATCH

A father and his son were driving through the Northern Adirondack mountains one day when they came to a ledge of rock showing great grooves running across it in parallel position. The boy at once exclaimed: "Oh father, look at those big scratches!" Sure enough that's what they were and any of us who drive that way can see them to this day. Such scratches may also be seen on countless other ledges and also on loose pebbles and boulders all over the northland of America. What are they?

Geologists tell us that the Northern portion of our country was once completely covered with great glaciers or sheets of ice, hundreds or thousands of feet thick. In many instances, pieces of quartz, or other hard substances, became frozen into the ice mass on the under side. As the great mass moved across the rock ledges, the hard substances scratched the ledge and thus left indelible evidence for all time, not only of the glacier's presence in those particular localities, but also of the tremendous power which it exerted as it ground its way across the ledges of rock.

But it is not necessary to go outside of our own homes to find scratches. They are everywhere about us, on our silver-ware, our kitchen utensils, our tables and floors, and they always have the same significance. What is it? Simply this, that the substance producing the scratch is harder than the one scratched.

Seven specimens are before us for pleasurable study. They are the first specimens we ever bought. What shall we do with them?

The most attractive one is six-sided, colorless and as clear as glass. Let us draw a sharp point or edge of this specimen across each of the others. We see that it has left a scratch on each of the others which we cannot blow off or wipe off.

Scratching one mineral with another enables us to decide which is the harder of the two, for the harder of any two substances will scratch the softer. If the six-sided specimen will scratch the other six, it must be the hardest of them all and we will mark it number seven.

Next let us see whether we can scratch number seven with any of the others. No, we cannot. If we think for a moment, we will conclude that *hardness is resistance to scratching.*

Let us reason further with ourselves as to the meaning of a scratch. As we motored along the road yesterday we saw a farmer plowing.

What was he doing? Simply scratching the surface of the earth with his plow, but in doing so his plow pushed the soil aside, leaving a furrow. Are we not doing the same thing when we test the hardness of a mineral? The harder mineral pushes aside the minute particles of the softer mineral and leaves a furrow or scratch on its surface. We might, therefore, say that *hardness is the resistance which the minute particles of any substance offer to another trying to push them into a new position.*

We noticed in scratching our specimens that some of them were much more easily scratched than others, and that deeper furrows were left on them. We also noticed that the one which was most deeply scratched had a greasy feel. Such a feel is characteristic of very soft minerals. Let us test this specimen and see whether it is really the softest of them all. Yes, each one of the others scratches it, so we can safely call it number one.

Selecting next the specimen with four smooth surfaces, the adjoining ones being at right angles to each other, let us try scratching the other minerals with it. We find that it will scratch all of them except number seven, so it must be number six. Using the same method with the other specimens, we will soon have them all arranged and know their relative hardness.

The *scale of hardness* consists of ten minerals, arranged according to their hardness from the softest to the hardest. They are:

1. Talc; 2. Selenite; 3. Calcite; 4. Fluorite; 5. Apatite; 6. Feldspar; 7. Quartz; 8. Topaz; 9. Corundum; 10. Diamond.

We have already made the acquaintance of the first seven and now we have their names. They are all common minerals and we shall doubtless meet all of them many times in the future. The last three are comparatively rare minerals and we are not very likely to meet them in the field, but their great hardness makes them important, as we shall soon see.

Do not get the idea that number three in the scale of hardness is three times as hard as number one, or that number seven is seven times as hard, or that number seven is seven-tenth's as hard as number ten. The number merely indicates the relative hardness. Selenite is always harder than talc; calcite is always harder than selenite; and so on. On the other hand, some specimens of a mineral may be harder than other specimens of the same mineral, though this is not usually the case. Hardness is generally quite a uniform characteristic and it is usually regarded by mineralogists as one of the safest guides in the determination of minerals. It is always mentioned in the scientific description of a mineral.

It is a good idea to have the minerals in the scale of hardness handy for reference. Some collectors make it a rule always to carry a little piece of quartz with them, for they know there are so few minerals harder than quartz, that if one is found which cannot be scratched by quartz, it is worth while to investigate further to ascertain whether it may not be something rare or of commercial value.

There is another little scale which is useful in roughly testing hardness in the field. Here it is:

(a) Minerals scratched by the finger nail have hardness of 2.5 or less.

(b) Minerals that will not scratch a cent, but are too hard to be scratched by the finger nail, have a hardness between 2.5 and 3.5.

(c) Minerals that will scratch a cent, but are themselves scratched by a good steel knife, have a hardness between 3.5 and 5.5.

(d) Minerals that are not scratched by a good steel knife, must, therefore, be over 5.5.

You will find it a good idea to keep a record of the hardness of all the minerals you test, arranging them in regular order. You will soon find that the number of soft minerals is much greater than the number of hard ones and that most of the common minerals are not very soft.

In testing the hardness of minerals great care should be taken to make sure that one mineral really has scratched the other and has not left upon it merely a mark or a ridge of its own powder. When you draw a piece of chalk across a blackboard, you are simply making a white chalk mark on the harder surface of the board. When a true scratch has been made, you cannot rub it off with your finger as you can a mark or streak of the powdered mineral.

Remember too that minerals are sometimes altered by long exposure to the atmosphere and rendered much softer than they were at first. The commonest illustration of this is the change of hard feldspar, hardness 6, into soft kaolinite or clay, hardness 2. Corundum, hardness 9, is very frequently altered on the outside into mica, hardness 2.5, or to some other mineral much softer than itself. These changes are, however, usually apparent to the eye. If the mineral has a mealy or porous look, it is probably not in its original condition and is likely to be much softer than its typical hardness.

Let us see how a test of hardness will aid in identifying minerals. When you are off on a hike, and come to a ledge of rock, if your knife-blade will scratch it, you can be sure that it is not any rock which is largely composed of the hard mineral quartz, such as quartzite or sandstone. It is easy to distinguish between feldspar and calcite by testing their hardness. These minerals often look much alike and even deceive

an expert, but if you are able easily to scratch a specimen with your knife-blade, you can be sure that it is not feldspar or any harder mineral, such as quartz.

Hardness is also one of the most important characteristics of a gem. Diamond wears so well because of its unequalled hardness. Ruby and sapphire, two very valuable precious stones, are next to diamond in hardness, each being a variety of corundum, number nine in the scale. Chrysoberyl, hardness 8.5, ranks next; then come topaz, spinel and the different varieties of beryl, including emerald, morganite, aquamarine and golden beryl, all of which are approximately 8. A knowledge of the hardness of precious stones has great practical value because it aids in the selection of stones which will wear well if they are to be subjected to rough usage.

Abrasives. Hardness enters even more practically into everyday life through the use of hard minerals as abrasives. These are hard substances used in grinding softer ones. You will find it most interesting and profitable to read up on abrasives, a subject which can scarcely be more than touched upon here.

Diamond, of course, is by far the most valuable of the abrasives. It is one of the few minerals whose hardness varies greatly in different forms or different localities. Thus the diamonds of Australia are much harder than those of South Africa, and the black variety, known in the trade as "carbon" is much harder than the gem diamonds, and is the hardest substance known. For this reason, it is in large demand for diamond drills and commands exceedingly high prices. "Bortz" or "bort" is diamond which is not clear enough to be cut into gems. It is used largely by lapidaries as an abrasive.

The next hardest natural abrasive is corundum. It was formerly in much larger demand than at present owing to the fact that a substance known as "carborundum," manufactured in electric furnaces at Niagara Falls, is harder and can be produced easily in unlimited quantities and of uniform quality. It is interesting to note that a mineral of the same composition as carborundum has been found in very minute quantities in the Canyon Diablo meteorite in Arizona, and has been given the mineralogical name of moissanite. Corundum is an excellent abrasive for many purposes. It was formerly extensively mined in North Carolina, Canada, India, and other parts of the world and more recently the Transvaal in South Africa has been shipping considerable quantities.

Corundum, naturally mixed with magnetite, is called emery, and prior to the discovery of carborundum, it was extensively used for grinding. Emery is inferior in hardness to corundum, but superior to all other available natural abrasives except diamond.

Garnet (hardness 7.5) and quartz sand (hardness 7) are the most used of the other natural abrasives. They are chiefly employed glued to paper forming garnet paper and sand paper. There are mines of garnet in the Adirondack Mountains in New York, also in New Hampshire and North Carolina. They would be good goals for motor trips. It might surprise you to learn of the many uses for garnet and sand papers. They are excellent illustrations of the practical applications of minerals to commercial and household needs. Each tiny grain performs its part, because of its hardness, in scratching away the irregularities of the softer surfaces to which they are applied.

Another very common way of applying abrasives is by binding and cementing together their powder into wheels, such as emery wheels and certain types of grindstones. Many grindstones, however, are made of sandstone, a rock which is chiefly composed of grains of sand.

In nature we see evidences of abrasion all around us. Any stream bed or the beach of an ocean or lake, bears testimony to countless millions of scratches which the harder masses of rock or mineral have made on others softer than themselves, gradually wearing them away until they become only grains of sand. All around us, therefore, we find answers to the question: "What is the meaning of a scratch?" The study of minerals transforms the nasty scratch into an object of intense interest.

Chapter 6

TENACITY, OR THE WAY A MINERAL HOLDS TOGETHER

It is natural to admire a man with tenacity of purpose. It is he who reaches the top of the ladder of achievement. He does not know the meaning of the word fail. Like the English bull-dog, he holds on. So it is in the mineral world. Those minerals which exhibit the property of tenacity most perfectly are those which stand up against any assault which is made against them by forces tending to tear their particles apart. The tenacious minerals might be described as the shock troops of the mineral kingdom.

Hardness and tenacity are closely related properties, yet there is a marked difference between them. We have learned that hardness is the resistance which the minute particles of any substance offer to another body trying to push them into a new position. *Tenacity is the resistance which the minute particles of any substance offer to another body trying to completely separate them.* The Latin word, *tenacitas,* from which tenacity is derived, means *hold fast.*

Tenacity manifests itself among minerals in several different ways, the most notable of which are malleability, ductility, and flexibility.

Malleability. Take a copper cent. It can be readily scratched so that you know it is not hard. Try to break it by pounding it with a hammer and you not only find that it is impossible to do so, but instead of its breaking, it is flattened out more and more until eventually you can produce a thin sheet. There is a Latin word *malleus,* which means hammer, or mallet. How natural it is, therefore, to call such substances which can be flattened out with a hammer or mallet without breaking, *malleable,* and to call this property *malleability.*

You can learn something about the malleability of iron by watching the country blacksmith making horseshoes. What do you think about the great rolling mills which make sheet iron? Are they taking advantage of the malleability of iron? Can you not picture the rolling process as subjecting the iron to an almost infinitely great number of blows of a hammer?

There are not many minerals which show this property of malleability, but it adds very greatly to the usefulness of those which do possess it. Gold is the most malleable of all minerals, it being possible for the skillful gold-beater to hammer it into sheets so exceedingly thin that it takes 280,000 of them, piled one on top of another, to make a pile an inch high. Gold in this form, is called "gold leaf." If you watch a sign painter using it, you notice that it is necessary to keep tissue paper

between the leaves of gold because they are too delicate to be touched, but must be lifted up on the paper.

The only minerals which are truly malleable are the metals, and this is one of the most important distinguishing properties of the metals.

Ductility. Another property of the metals which is closely related to malleability is ductility. Minerals are said to be ductile, or to possess the property of ductility, when they can be drawn out into wire. There is a Latin word, *ductilis,* derived from the verb, ducere, which means "to lead," that is, easily led or drawn out, just like taffy is drawn out.

Copper and steel are much more used for wire than any other metals, but this is only because they are cheaper. Gold and silver are even more ductile, and as aluminum is cheap, it also is used. It may not be easy for you to demonstrate this property with your specimens, but just think of the tremendous importance of ductility in our every-day life. If it were not for this property of the metals, we would have no electric lights, no trolleys, no radios, no suspension bridges, no elevators, for all of these and many other inventions are dependent upon the use of wire.

In nature, manifestations of the property of ductility may be seen in the beautiful specimens of wire gold, silver and copper.

How shall we link up this property of ductility with tenacity? Is it not true that copper is more ductile than lead because its particles offer greater resistance to being completely separated while being drawn out? We might put it another way by saying that copper does not break so easily as lead and that this resistance to breaking is proof that its particles hold together more tightly than those of lead, which is the same thing as saying that copper has greater tenacity than lead.

There are several other manifestations of tenacity among minerals which have not as great commercial value, but which it is well to understand because they help us to determine minerals. We can note these but briefly.

Sectility. The word sectility is derived from the Latin, *sectilis,* cut. If you take the specimen of selenite in your scale of hardness and try to cut or whittle it with your knife, you find that you can cut off shavings of selenite. Such a mineral is called sectile. Because it is not a common property, it helps to identify the few minerals which possess it. Among these are selenite, talc, wurtzilite. If we pound the shavings of any one of these minerals, we will find that they quickly fall to powder. This shows that the difference between sectility and malleability consists in the manner in which the particles of the mineral are held together.

Flexibility. Sometimes the same mineral will show two quite striking properties. Selenite is such a mineral, for besides being sectile, it is also flexible, or shows the property of flexibility. This means that it *can be bent without breaking and will stay bent.* If you take a slender little crystal of selenite, you can not only bend it, but by holding it firmly in one hand and pressing it with the thumb and forefinger, of the other hand, you can bend it at an angle and then by shifting to another part of the crystal, you can repeat the operation, producing the effect shown in figure 23. You can certainly make some odd looking specimens when you bend the crystals in two or more directions.

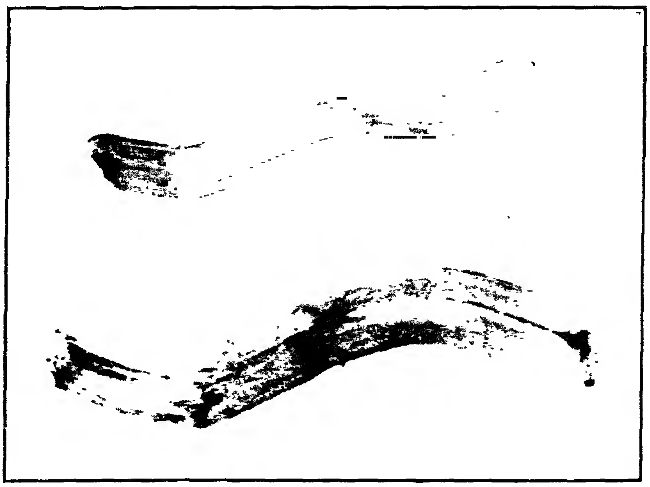


Figure 23. Selenite Crystals Showing Artificial Bending

Elasticity. If you take a sheet of mica and try to bend it, you will find that it acts differently from selenite, for while you will succeed in bending it, as soon as you release the pressure, it will spring back to its original position. *A mineral which will bend and spring back is called elastic* and this property is termed *elasticity.* All of the micas are elastic, but as they weather they lose their elasticity.

Brittleness. Many a collector has learned to his sorrow about another property of minerals when he has found a fine specimen in the rock and tried to break it out, only to have it go to pieces. This was because the mineral was *brittle*, or showed the property of *brittleness*, due to the fact that the particles of the mineral are not held firmly together, or offer but very slight resistance to being completely separated. Of course, there are degrees of brittleness, for some minerals break so easily that they can scarcely be touched, while others break

with considerable difficulty. Such familiar words as *fragile, weak,* and *tough* are used to describe them and they are self-explanatory. When you begin field collecting, you will soon meet minerals which illustrate these and other properties. What a satisfaction it will be to know about them in advance.

Chapter 7

CRYSTALS—THE FLOWERS OF THE MINERAL KINGDOM

In the month of June we are thrilled by the beauties of the flowers in the garden, but soon they wither and die. We may experience similar delight by visiting a good mineralogical museum and there seeing the lovely flowers of the mineral kingdom which are permanent and never die and are always ready to reward us for the time we devote to their study.

What a wealth of captivating crystals there are! We see little diamond crystals, charming groups of gold crystals, magnificent large crystals of stibnite, sparkling crystals of quartz, rich golden crystals of calcite, delicate blue topaz crystals, gorgeous red wulfenite crystals, and hosts of others, each different from all the others. What a wonderful garden it is! How entrancing it will be to learn about its flowers!

What are crystals? We need not go outside our own homes to begin our study of them. Right on our dining table there are multitudes of them. Pick up the salt cellar and shake a little salt into your hand and examine it with your pocket lens. If you have never done this before, you will be amazed to find that table salt consists of great numbers of tiny cubes, figure 24. These cubes are true crystals of salt and each

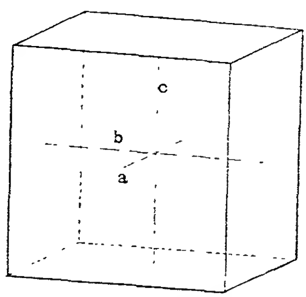


Figure 24. Cube Showing Three Axes

one is like every other in certain particulars. How many sides or "faces" have they? Is the angle between any two adjoining faces the same as the angle between every other pair of adjoining faces? We can see almost at a glance that these cubes all have six faces and that the angles are the same. Possibly, if we look closely, we shall see that some of them are somewhat rounded, while an occasional one may be a little elongated, but these are imperfections which we must expect to find in natural crystals, for it is practically impossible to find them perfect.

It is for this reason that it is best, when the study of crystals is first taken up, to learn about their ideal forms.

An expert workman might make a perfect cube of glass or metal or wood, so that its faces would be perfect squares and the angles between the adjoining faces precisely alike, but such a cube would not be a crystal. There is a most interesting difference between such a model and a true crystal formed by nature or in the laboratory. Externally their forms may be identical, but in a crystal there is a definite internal arrangement of the atoms of which it is built, while no such arrangement exists in models of crystals. For a hundred years it had been assumed that crystals had this definite internal structure, but it was not until 1912 that the great crystallographer, Laue, by aid of X-rays, made the structure actually visible. A microscope may never be made powerful enough to enable us to see the tiny atoms of which all crystals are built, but photographs made with X-rays do actually show regularly arranged dots which are produced by vast accumulations of these atoms in definite layers or planes at fixed angles to other planes. It is thus proved that there exist certain great forces which act between the atoms inside crystals and compel them to assume the forms which we see. We have entered a great and fascinating field for study, in which a vast amount of work is now being done by research workers. While, as beginners, we may not be able to proceed very far in the study of the structure of crystals, there are many things we may learn about them which are well worth knowing.

In view of what we have already learned, if we were asked, "what is a crystal?", we could reply, *a crystal of a mineral is the regular form which it assumes, as a result of the attraction between the atoms of which it is built being exerted in fixed directions when it is in process of formation.*

We are not, at present, able to see the crystallizing forces at work, but we can see the crystals forming. Watch a pool of water on the sidewalk or the moisture on the window pane, when the temperature is falling below the freezing point, and you can see ice crystals form. Possibly you have seen the projection on the screen of the formation of various crystals of chemicals. If you make a strong solution of alum or blue vitriol in a tumbler and suspend a crystal of either by a thread in the solution for a day or so, you can produce fine crystals of much beauty, though you may not be able actually to see them grow.

A very large majority of all minerals are found in crystals and in some of them the number of distinct forms which are combined in a single crystal is large. The common mineral calcite leads all others in the

great variety of its forms, indeed a collection of 800 or more specimens might be gathered together if all the forms of calcite could be brought to one place. It is most surprising that with many hundreds of minerals forming crystals and some of them producing an almost endless number of forms, some of which are highly complex, crystallographers have been able to classify them all into only six great systems. It will be possible for us to learn the fundamental differences between these systems, and if we do so, crystals will hold a far greater fascination for us, whenever we see them.

The first thing for us to do is to use our imaginations, for strange as it may seem, the classification of crystals depends upon certain wholly imaginary lines, called *axes,* which are assumed always to pass through the centers of the crystals. The differences between the systems are differences in the number, length, and position of these imaginary axes. In five of the systems there are three axes, while the sixth system has four axes. In one system they are all of the same length, in all of the others the lengths are different. In three of the systems all of the axes are at right angles to each other, while in the other three, one or more of the axes are inclined to the others. As we study these six systems, we will see what marvelous changes in the forms of the crystals are brought about by these differences in their axes, and on the other hand, we will be amazed to find if we examine many thousands of crystals, that the angles between like faces of any mineral are always the same.

Our search for crystals will be pursued with new zeal as we understand more and more about their wonders. Let's see what we can learn about these marvelous crystals.

Chapter 8

CHARMING ISOMETRIC CRYSTALS

Isometric Crystals. With keener interest than ever before, because of our preliminary studies of crystals, we make another visit to the museum and look at the large crystals of halite, whose acquaintance we have already made as table salt. Next we examine the galena crystals and here again we find cubes among them, though most of the specimens show other faces besides those of the cube. We find this is true also of fluorite and pyrite, over whose glorious crystals we become more enthusiastic. Some of their forms are really quite mysterious and perplexing. We shall learn more about these later.

Just now we are most interested in laying a broad foundation for our study of crystals and this we can gain by a careful investigation of the important forms found in the first of the six systems of crystals, which the crystallographers call *the isometric system.*

Isometric! What does this mean? It is derived from two Greek words, *isos,* meaning *equal,* and *metron, measure: equal measure.* Think for a moment how this applies to the cube. You remember that the length and breadth of each of its faces are equal and that all of its angles are equal, or are right angles.

How a potato aids crystal study. It seems like a far cry from a potato to a crystal, but let us see how a potato can help us to understand several of the forms in the isometric system. We want to make from it the crystal form shown in figure 25, called the *octahedron,* so named because of its eight bases, the Greek *octa,* meaning *eight,* and *edra,* meaning *base.* Select a big round potato and cut from it with a sharp paring knife, a two inch cube. Measure the sides with a rule and see that all of the edges are the same length and try to make the angles perfect right angles. Take the rule and with a sharp-pointed indelible pencil, draw lines lightly across each face diagonally from corner to corner. They will meet at the center of the faces. It is easy now for us to imagine that there are lines drawn from the center of each face to the center of the face opposite to it, and we know that they would meet at the center of the cube and would all be at right angles to each other and of the same length. Let us bear these facts in mind while we proceed with our work.

Now let us mark the center of each edge of the cube with our indelible pencil and draw lines from each point to those adjoining it. If we do this accurately, we shall have marked off a square on each face of the

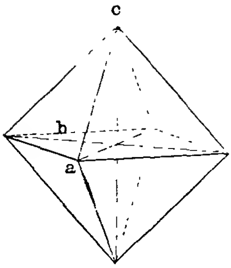


Figure 25

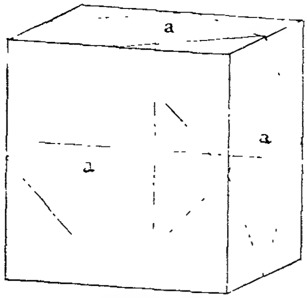


Figure 26

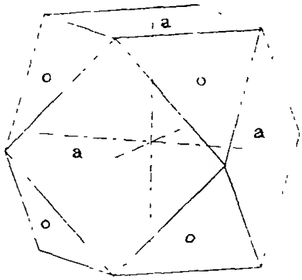


Figure 27

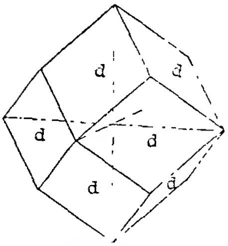


Figure 28

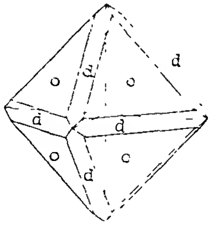


Figure 29

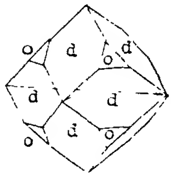


Figure 30

Figures 25–30. Forms of Isometric Crystals

cube, as shown in figure 26. Now let us take our knife and gradually shave off the eight corners of the cube until we have reached the lines. We shall have produced a form like figure 27, which shows, still, parts of the six faces of the original cube marked *a* and eight new faces marked *o*. This form is very common in galena and we noticed it when we were at the museum.

Let us continue to shave off the potato in the same direction, a little at a time, first above and then below, parallel with the eight new faces. At last we succeed in cutting away all of the cube faces and there will be only the faces of the octahedron, as shown in figure 25. Note that the distance between the points of the octahedron is the same as that between the centers of the opposite faces of the cube, figure 24, therefore, if it were a true crystal, it would belong to the same system of crystals as the cube. When you go out collecting be on the lookout for little black octahedrons of magnetite: they are very common in some localities. Chromite too almost always occurs in octahedrons when it is crystallized and this form is common also in cuprite and diamond.

All crystals which have three axes of the same length and at right angles to each other, belong to the isometric system.

If the octahedron produced from the potato cube were not so small, we could proceed to make another isometric form, the dodecahedron.

figure 28, from the octahedron, by shaving off its edges, as shown in figures 29 and 30.

Crystals of cuprite and betafite often show such combinations of forms as these. We can, however, produce the dodecahedron more easily direct from the cube, so let us start with a fresh potato, make a two-inch cube, then slice off its edges, a little at a time, all around. At first it will appear like figure 31, which we sometimes see in fluorite. Counting the number of new faces, we find there are twelve of them, and if we continue to cut away all of the cube faces, *a* we produce the form shown in figure 32. Finally, all of the *a* faces are removed, leaving only the new faces *d* and the form is produced which is shown in figure 28, called *dodecahedron*, from the Greek *dodeca*, twelve and *edra*, base. We shall often meet the dodecahedron in the mineral garnet. In certain localities hundreds of crystals of this form can be picked up loose in the soil, while many thousands are imbedded in the near-by ledges of rock.

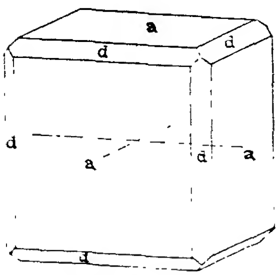


Figure 31

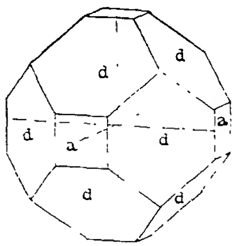


Figure 32

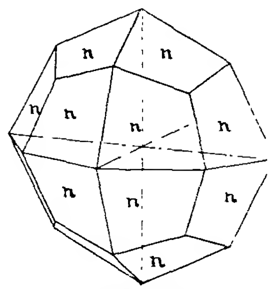


Figure 33

Figures 31–33. Forms of Isometric Crystals

Another very common form in garnet is the *trapezohedron*, figure 33. If we look at it carefully, we see twelve faces and we know there are twelve more on the invisible half of the figure, making twenty-four in all. Each is a "trapezium," which is a four-sided figure with none of its edges parallel. Trapezohedrons are the commonest forms of crystals of analcite and leucite.

The *pyritohedron* is so named because it is one of the commonest forms in the mineral pyrite. It is shown in figure 34. You may find it difficult to secure a simple pyritohedron, for while it is so common, it is usually combined with other forms, such as the cube and octahedron. One such combination of unusual interest is described on page 66. The pyritohedron has twelve faces, the same as the dodecahedron, but look at them and you will see one striking difference—the faces of the pyritohedron, unlike the dodecahedron, have five edges instead of four, or

are pentagons. It is for this reason that the pyritohedron is sometimes called the pentagonal dodecahedron.

It is customary where there are two or more forms combined in one crystal to speak of the form with the smaller faces as modifying the one with the larger faces; thus in figure 31 we see the dodecahedron (*d*) modifying the cube (*a*); while in figure 32 the cube (*a*) modifies the dodecahedron (*d*). If the cube and octahedron are equally developed, as in figure 27, the form is called a *cubo-octahedron*, which, as we have seen above, is very common in galena.

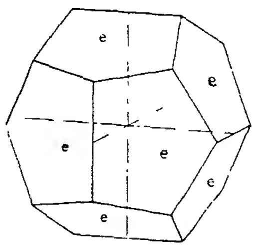


Figure 34

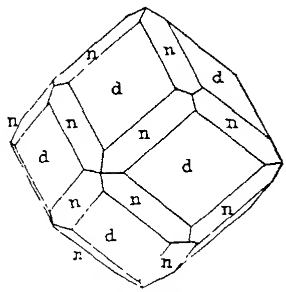


Figure 35

Figures 34, 35. Forms of Isometric Crystals

If you become throughly familiar with the five simple forms of isometric crystals above mentioned, and their combinations, you will have gone a long way toward identifying any isometric crystal you may see. and you will meet many of them. for the number of isometric crystals in nature is very great. Often two or more of the forms are combined in the same crystal, as shown in figures 27, 29, 30–32 and in figure 35, which shows the common form of the handsome garnet crystals from Alaska which adorn many collections.

Most minerals have certain characteristic forms in which they occur much more frequently than in any other forms. Thus in garnet the forms we have already met in figures 28, 33 and 35, are much more common than any others. while the cube. which is so abundant in many others minerals, is almost never seen and the octahedron, a very common form in numerous minerals. is very rare.

You will surely derive much pleasure from identifying the different forms of isometric crystals. Many. which at first may seem very complex, will. in a little while. be easily understood and you will be able to name the faces as soon as you see them.

Chapter 9

FOUR GROUPS OF CRYSTALS

Tetragonal Crystals. If you compare figures 25 and 36, you will see at a glance a marked difference, even though each of them has eight triangular faces and their three axes are at right angles. You notice that the vertical axis is much longer in figure 36 than in figure 25 and much longer than the two horizontal axes. In figure 37 the vertical axis is shorter than the two horizontal axes, which are of the same length. We have thus quickly learned not only the difference between the first and second of the great systems of crystals, but also that in this second system called the *tetragonal system*, there are *three axes at right angles to each other, the vertical axis being either longer or shorter than the two equal horizontal axes.*

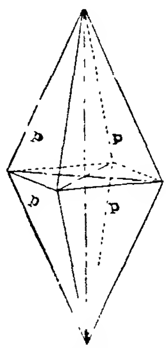


Figure 36

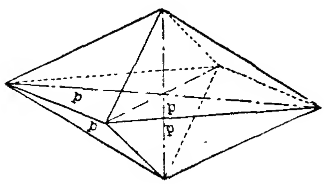


Figure 37

Figures 36, 37. Tetragonal Pyramids

Notice that the faces of figures 36 and 37 are marked "p." They are called "pyramids," and surely if we were to cut number 37 in half, horizontally, the upper half would be much like the great pyramid in Egypt. These forms are really double pyramids. Let us remember, therefore, that in the tetragonal system, it is not the custom of crystallographers to speak of octahedrons, but of pyramids. The reason for this is very simple; all of the edges of the faces of the octahedron are equal, while in the pyramid of the tetragonal system the horizontal edges are always of different lengths from the other edges.

Figure 38 represents the tetragonal form which we would produce by piling one potato cube on top of another. This form is called a *square prism*. It is natural to call the face upon which the cubes are

resting the *base*. This term is used for both the top and bottom faces, which close the open form of the prism, its sides, or vertical faces, being called *prismatic faces*, or simply *prisms*.

In figure 39 we see a combination of a prism (m) with quite a flat pyramid (p). This form is frequently seen in the mineral zircon, a mineral which was formerly regarded as rare, but which has been shown to be present in all granite rocks, though usually in minute crystals. Be on the lookout for it and you will recognize it by its form.

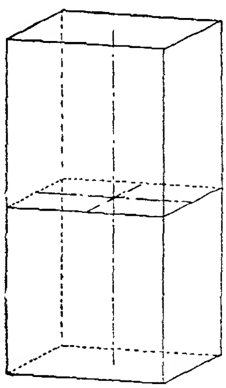


Figure 38

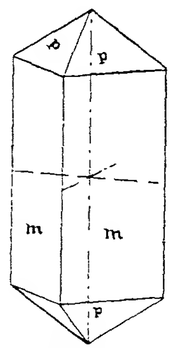


Figure 39

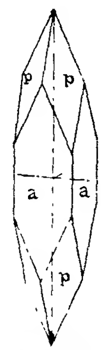


Figure 40

Figures 38–40. Forms of Tetragonal Crystals

Figure 40 has prismatic and pyramidal faces, just as figure 39 has, but how different it looks. Can you see what the differences are? Note first that the pyramids are much steeper than in number 39; then look at the way they meet the prism faces. There is not a horizontal line running around the crystal, as in number 39, but a zigzag. The vital difference is that in figure 40, there is a different kind of prism, which is lettered a instead of m. Just imagine slicing off the vertical edges of the prism faces in figure 39 and you will be able to locate this new kind of prism, which forms equal angles with the faces of the prism m on either side of it. You will see it in many specimens of the beautiful mineral apophyllite from Andreasberg, Germany, from Berufiord, Iceland, and other localities. If you were to cut off the points of the crystals horizontally, replacing them by the two bases, you would develop a form of apophyllite which was once fairly common in the trap rocks of New Jersey, near to New York City.

While there are not very many tetragonal minerals, some of them are of great importance. Chalcopyrite is one of them. Its crystals may puzzle you considerably, but if you remember that its common form,

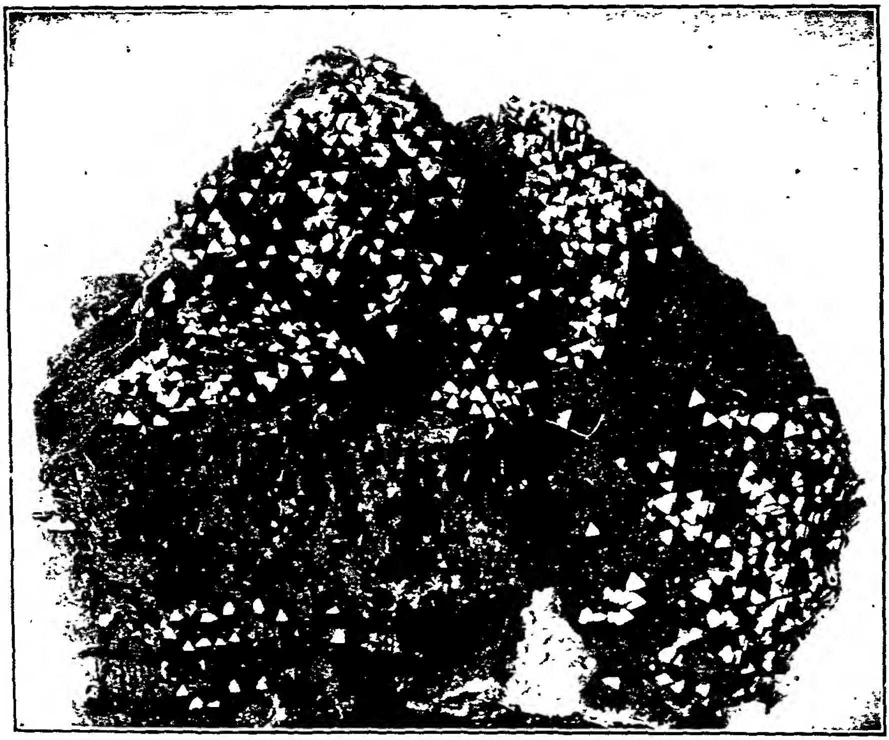


Figure 41. Chalcopyrite Crystals (Sphenoids) on Sphalerite; near Joplin, Missouri

known as a *sphenoid,* is one in which only half of the pyramidal faces are developed, you may thus see why there are but four faces instead of eight. It occurs in the Joplin, Missouri region in beautiful, brilliant little crystals of this type on very attractive crystallized dolomite, figure 198, and sphalerite, figure 41. Such specimens would be worthy additions to your permanent collection.

Cassiterite is another mineral which crystallizes in the tetragonal system. Its crystals are usually very complex. Rutile is a fairly plentiful mineral whose crystals are almost exactly like those of cassiterite. When you visit the public museum look up these minerals and also wernerite and vesuvianite, two rock-forming minerals, also beautiful wulfenite. Even though tetragonal minerals are not plentiful, it pays to know about them, for some of them are among the most spectacular of all species.

Orthorhombic Crystals. Two Greek words briefly describe the third great system of crystals; they are *orthos, straight* or *right,* and *rombos, a rhomb.* From these words the word *orthorhombic* has been derived to describe *crystals having three axes at right angles to each other, all of*

different lengths. One of the simplest forms of the orthorhombic system is shown in figure 42. How does it differ from the cube of the isometric system and the tetragonal prism? First note that, because the vertical and horizontal axes are of different lengths, its vertical faces, lettered

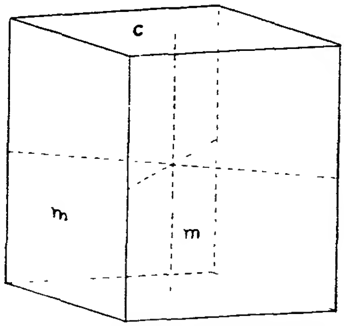


Figure 42. Simple Orthorhombic Form

m, are rectangles, as in the tetragonal prism, instead of squares, as in the cube. Second, look down on the form from above, figure 43, and note that its top and bottom faces, lettered *c*, are rhombs, which shows that the angles between the prism faces are not right angles. The fundamental, or "unit," prism occurs in all of the systems except the isometric,

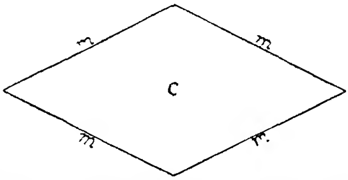


Figure 43. View of No. 42 from Above

mental, or "unit," prism occurs in all of the systems except the isometric, and is always lettered *m*, while the horizontal base, which combines with and closes the prism at both ends, is lettered *c*.

Figure 44 shows a simple crystal of barite, with the same forms as figure 42, but with the vertical axis much shorter, thus producing a

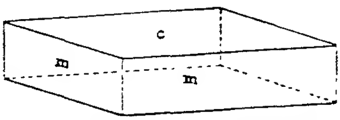


Figure 44. Simple Form of Barite Crystal

crystal which is tabular parallel to the base, *c*. This is a common form in barite, though there are often other faces present which sometimes are so large as to make the prism and base inconspicuous.

There are double pyramids in the orthorhombic system, such as figures 45 and 46, which resemble those of the tetragonal system, and sometimes, at first sight, a simple double pyramid might be thought to belong to the tetragonal system, but it can be readily distinguished by looking down on it from above the terminal point, and noticing that a horizontal section of the crystal would be a rhomb and not a square. A crystal of sulphur well illustrates this characteristic.

There are about two hundred different minerals which crystallize in

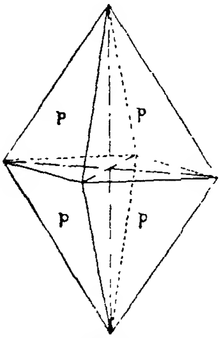


Figure 45

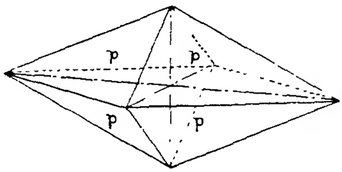


Figure 46

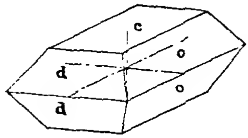


Figure 47

Figures 45—47. Other Orthorhombic Forms

the great orthorhombic system. Among them are such outstanding species as topaz, figures 158–160, aragonite, chrysoberyl, figure 163, staurolite, figures 99–101, barite, figures, 44, 47, 165, 166, celestite, anglesite, cerussite, stibnite and chalcocite. It is well to know something about their crystals, even though the forms of many are so complex as not to be easily understood. This very fact stimulates our ambition to study them and we shall have the mastery of their forms as one of our delightful goals.

Monoclinic Crystals. If you look at figure 48, which shows one of the simplest forms of pyroxene, you will see that the angles on its front face are all right angles, which indicates that two of its axes are at right angles to each other. On looking at the other faces, however, it is evident that the third axis is inclined to the vertical, for this crystal has a distinctly bent-over appearance. If you were to hold such a crystal with its face *a* vertical, the face *b* would also be vertical but the face *c* would be inclined so that the edge between *c* and *b* would not be horizontal. This is one of the characteristics of the fourth great system of crystals, known as the *monoclinic system*, in which *there are three unequal axes, two of which are at right angles while the third is inclined*

to the vertical. The forms cannot be studied in detail without considerable knowledge of geometry, but even the beginner will readily note the difference between them and the forms of the three systems already studied and when he meets a typical monoclinic crystal, with its characteristic inclination, he can be reasonably sure that it belongs in this system.

It will be worth your while to familiarize yourself with the appearance of some of the monoclinic crystals. A common form of selenite, shown in figure 49, will be frequently seen. Orthoclase is found in many different forms, some of which are most perplexing, but the simple shape

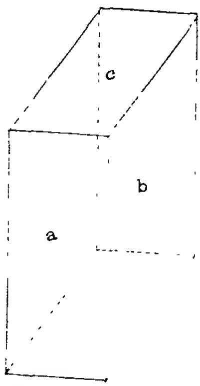


Figure 48

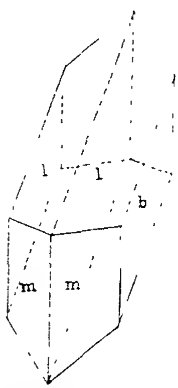


Figure 49

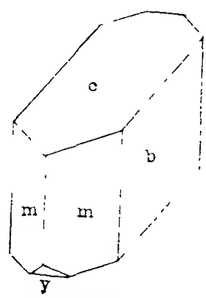


Figure 50

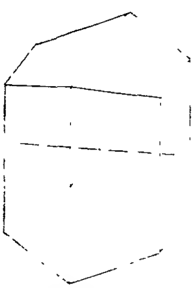


Figure 51

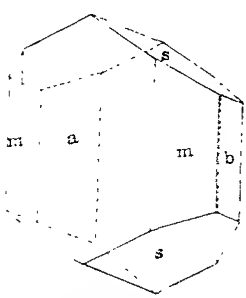


Figure 52

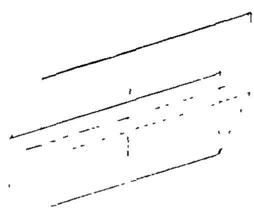


Figure 53

Figures 48–52. Forms of Monoclinic Crystals
Figure 53. Simple Form of Triclinic Crystal

shown in figure 50 is common in crystals from Goodsprings, Nevada, and other Western localities. Hornblende and augite are other common rock-forming minerals which crystallize in the monoclinic system. Common forms of their crystals are shown in figures 51 and 52.

The monoclinic is one of the largest of the systems and includes be-

sides the minerals above mentioned, such important species as borax, muscovite, phlogopite, epidote, titanite, azurite, and malachite.

Triclinic Crystals. The fifth and last of the great systems of crystals which have 3 axes is called the *triclinic*. As this word suggests, *the three axes are all inclined to one another and they are of unequal lengths* as

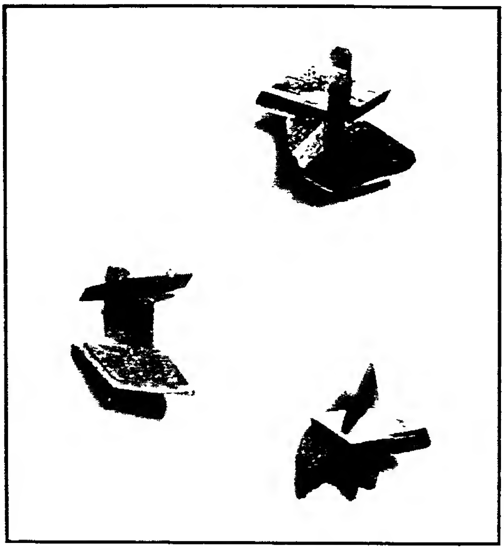


Figure 54. Axinite Crystals from Switzerland

shown in figure 53. Such a development leads to very complex forms whose study is beyond the scope of this book. Fortunately there are but few minerals which crystallize in this system and with the exception of the plagioclase feldspars, about which we shall learn more later on, none of them is of great importance. Rhodonite, kyanite and axinite, figure 54, are the other leading species.

Chapter 10

REMARKABLE SIX-SIDED CRYSTALS

Hexagonal Crystals. The most beautiful of all crystals are to be found in the sixth of the great systems, *the hexagonal. This is the only system in which there are four axes. Three of these are horizontal and of equal length, forming equal angles with each other, while the fourth axis is vertical and either longer or shorter than the others and at right angles to them.* While some of their forms are very complex, there runs through them all such manifest evidences of symmetry that we shall find it a real pleasure to study them and to unravel their forms.

The *hexagonal prism*, figure 55, is one of the simplest forms in this system. It is found in apatite, beryl and many other minerals. You cannot see its six-sided shape if you look at it horizontally from in front, but looking down on it vertically its sides appear like figure 56.

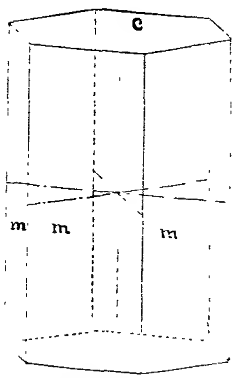


Figure 55

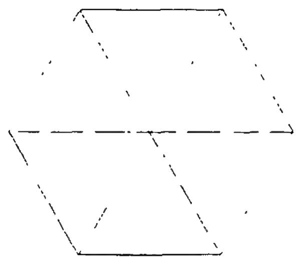


Figure 56

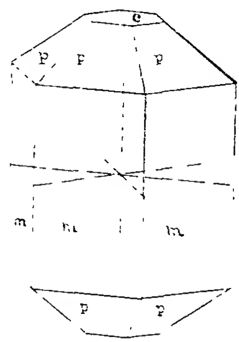


Figure 57

Figures 55–57. Forms of Hexagonal Crystals

If you have become at all expert in making crystal models from potatoes, you will find it worth while to make a hexagonal prism, then mark off with your indelible pencil the lines shown in figure 56, and also horizontal lines around the prism faces, one of them quarter way down from the top and another quarter way up from the bottom. Next shave off the six horizontal edges at the top and the six at the bottom, a little at a time until you have reached the horizontal lines, holding your knife at the angle shown in figure 57 and you will eventually produce the form shown in figure 57. Notice that these new faces are like the

pyramids of the tetragonal system, only there are six above and six below, instead of four; we shall, therefore, call them *pyramids*, marking them *p*. Part of the base, or end face, *c*, still remains. Now begin to shave off the horizontal edges at a steeper angle, a little at a time, all around, above and below, and you will eventually remove all of the base (c) and produce the form shown in figure 58. You now have a form showing a combination of the hexagonal prism and a double hexagonal pyramid. Such a form is frequently seen in quartz.

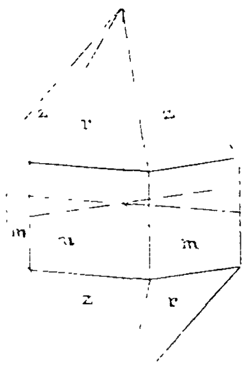


Figure 58

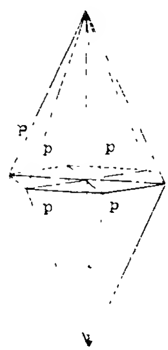


Figure 59

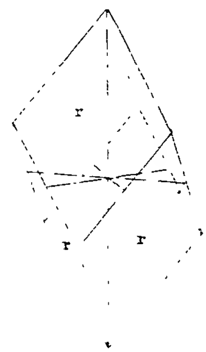


Figure 60

Figures 58–60. Forms of Hexagonal Crystals

If instead of starting to shave off the edges above and below the middle of the model, we started at the middle, the form shown in figure 59 would be developed. It is a *double hexagonal pyramid.*

Now let us use our imaginations a little, for it will probably be difficult for you to make models of the remaining forms with which we want to become familiar. Imagine that you are looking directly down on figure 59 and that you cut away half of its faces above and half below, choosing the faces below which alternate with those above instead of those which are opposite. Figure 60 shows the form which would be produced, only, of course, it would be relatively smaller. You see there are only half as many faces, and they are rhombs instead of triangles and the line between the upper and lower faces zigzags around instead of being horizontal. This form, all of whose faces are rhombs, is called the *rhombohedron.* There are many different rhombohedrons in the hexagonal system, depending upon the relative length of the vertical axis; if the vertical axis is relatively long, the rhombohedron will be steep, as in figure 61; if the vertical axis is relatively short, the rhombohedron will be quite flat, as in figure 62. The mineral calcite shows a

great variety of rhombohedrons, both steep, flat and intermediate. The rhombohedron is especially characteristic of the group of carbonates.

It may seem strange that quartz, figure 58, which almost always appears to be in hexagonal prisms, terminated by hexagonal pyramids, is classified among rhombohedral minerals. This is true of many other rhombohedral minerals, all of which occur with their parts in threes instead of in sixes, but in such instances the expert crystallographer is able, by certain tests, to detect the fact that the apparent hexagonal pyramids are really combinations of two rhombohedrons, while the apparent hexagonal prisms are combinations of two three-sided prisms. The terminal faces are, therefore, called rhombohedrons and not pyramids, and are quite different from simple hexagonal forms. Quartz crystals are so widely distributed that it is more than likely that you will have the opportunity of examining many of them, and if you do, they will become more and more attractive to you. It is quite probable

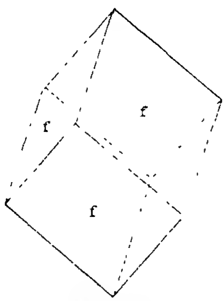


Figure 61

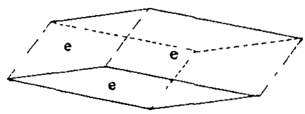


Figure 62

Figures 61, 62. Forms of Rhombohedral Crystals

that you will see crystals with but three terminal faces, or, still more commonly, crystals in which three of the faces are larger than the other three. As you press on in your studies you will find other interesting evidences of rhombohedral forms which at first you would be apt to overlook.

One of the most remarkable of these forms, shown in figure 63, is called the *scalenohedron*, from two Greek words *skalenos*, *unequal* and *edra*, *base*. Note that all of the triangles which form its boundaries are scalene triangles, that is, all of their edges are of different lengths. At first glance you may think this form is like a double hexagonal pyramid, but soon you will see that there are no horizontal edges, but that there is the same zigzag around the center as in the rhombohedron. A closer examination will show you that there are three pairs of faces above and that the upper faces alternate with those below. Sometimes the scaleno-

hedrons are very steep, as in figure 64, which means that the vertical axis is relatively long. Such a form in calcite is called "dog-tooth spar." Very frequently the points of the scalenohedron are cut off by the faces of the rhombohedron, as in figure 65, or, again, besides these faces, the prism may be present, which is one of the well-known forms at the Bigrigg Mine, England, as in figure 66. These are some of the multitudes of forms of calcite crystals with which we shall enjoy becoming acquainted.

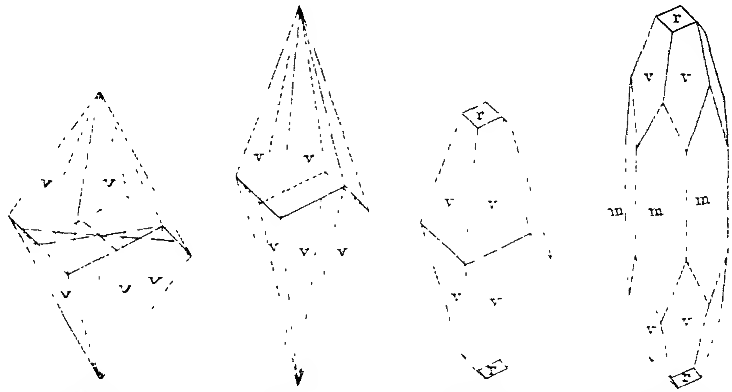


Figure 63 Figure 64 Figure 65 Figure 66

Figures 63–66. Forms of Calcite Crystals

Only a few of the simplest and most common forms of the hexagonal system have been mentioned. You can easily picture to yourself what a host of different kinds of crystals can be produced by combining rhombohedrons, scalenohedrons, pyramids, and prisms. You may easily meet with such forms in calcite, tourmaline, hematite or others of the many beautiful minerals of this great system which embraces a large number of important, common and attractive minerals. Doubtless the most beautiful of all hexagonal crystals are those of snow, a few of the hundreds of different types of which are shown in figure 67. What a glorious collection of crystals could be made if it were possible to keep the snow crystals!

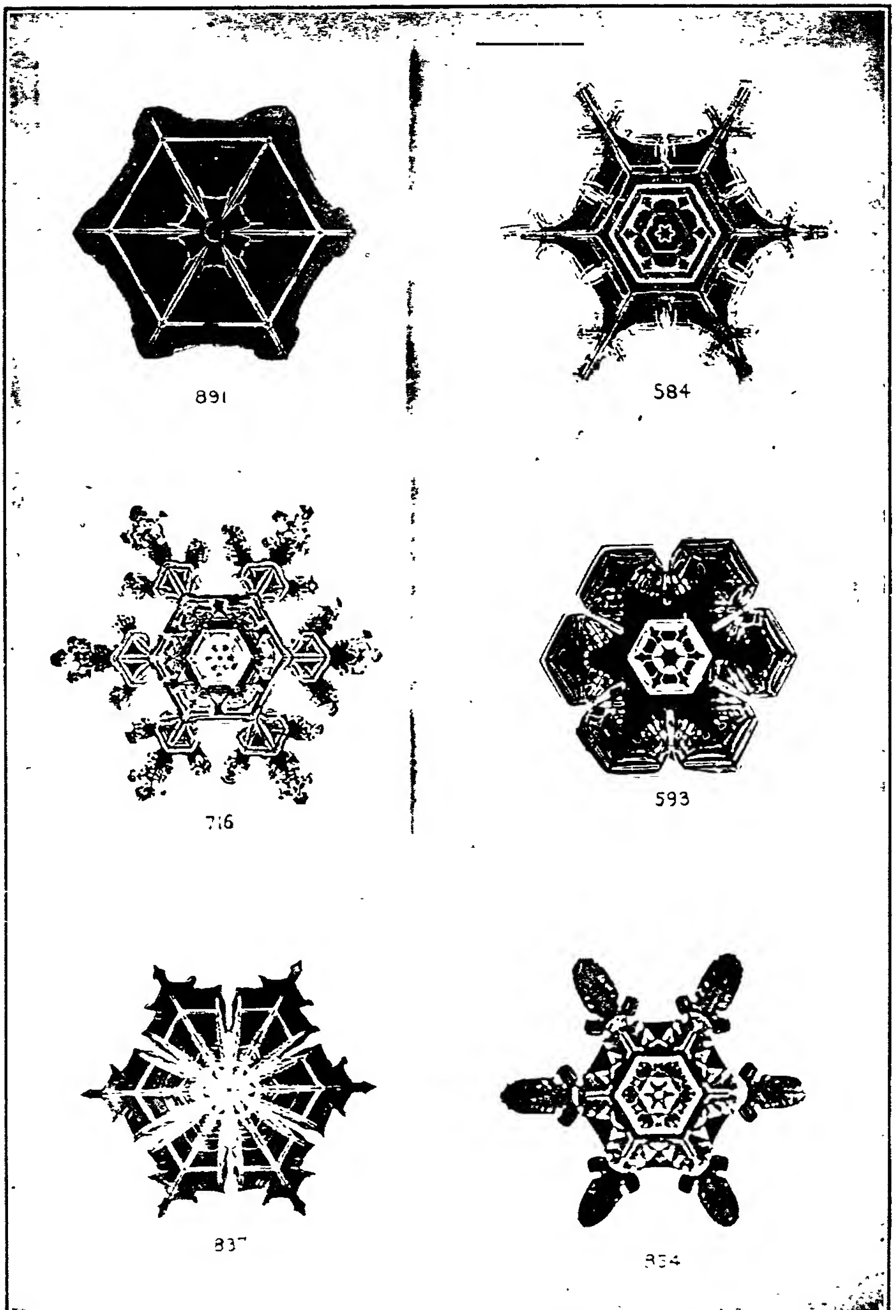


Figure 67. Microphotographs of Snow Crystals. (W. A. Bentley)

SUMMARY

We have learned that the all important distinctions between the six great systems of crystals are in the number, relative length and inclination of the imaginary lines called axes. Let us set forth the differences between the systems in tabular form.

Characteristics of the Six Systems of Crystals

System	No. of Axes	Inclination of Axes	Length of Axes
1. Isometric	Three	All at right angles	All the same length
2. Tetragonal	Three	All at right angles	2 equal. 3d longer or shorter
3. Orthorhombic	Three	All at right angles	All of different lengths
4. Monoclinic	Three	2 at right angles, one inclined	All of different lengths
5. Triclinic	Three	All inclined	All of different lengths
6. Hexagonal	Four	3 equally inclined. 4th at right angles to other 3	3 alike. 4th longer or shorter

The search for crystals adds immeasurably to the zest of mineral collecting. The best place quickly to get an idea of their beauty and variety is a good public museum, but remember that one crystal you find yourself, or for which you pay good money, is worth a score which you merely examine in another collection. Be constantly alert for "the flowers of the mineral kingdom."

Chapter 11

THE PRANKS OF CRYSTALS

Even crystals, which are supposed to be models of perfection in the mineral kingdom, sometimes play pranks on the crystallographer and it is for this reason that some collectors have a hobby of collecting freak crystals. There is much genuine pleasure to be derived from such a hobby, and much can also be learned about the forces which operate to produce differences in crystals.

We have already learned (see page 39) that it is practically impossible to find absolutely perfect crystals in nature, though we must bear in mind that, theoretically, the angles between their faces are constant. and, indeed, this constancy of angles is one of the essential characteristics of crystals. It seems all the more remarkable, therefore, to find freak crystals which, at least at first sight, seem to be so different from the typical forms about which we have learned as to make them more like forms in some other system of crystals. What are some of these freaks?

Stretched-out Crystals. If we pile up cubes, one on top of another, as shown in figure 68, we produce a tall and relatively narrow form, figure 69. If these cubes were very small and more of them were piled one on top of another, we would produce a very slender, or *acicular* form, figure 70. Other elongated forms are found besides those of cubes, for in other systems of crystals we have these so-called *acicular* crystals, such as of rutile in the tetragonal system, of stibnite in the orthorhombic system, of scolecite and crocoite in the monoclinic system and of tourmaline in the hexagonal system.

Possibly the most wonderful of all the stretched-out crystals are the cubes of cuprite elongated into hair-like forms, or *capillary* crystals, so-called from the Latin *capillus*, a *hair*. Cuprite of this variety, called chalcotrichite, is rare and highly prized. The finest specimens thus far found in the United States were discovered many years ago near Morenci, Arizona. It was possible at that time to secure specimens showing gradations all the way from a regular cube to the finest hair, but when these delicate hairs are examined under the microscope, it is distinctly seen that they are not round like hairs, but have square edges, proving that they are really elongated cubes. You may not be able to secure a specimen of this mineral, but if not, be sure to look it up the next time you visit a good museum, or get a collector who has microscope box mounts of minerals to show you its marvelous beauty.

As you view the sharp edges of the hair-like crystals, try to picture to yourself the battle of the crystallizing forces, the one which pulled the cubes out into hairs finally triumphing over the forces trying to make a perfect cube. Everywhere in the mineral kingdom we can see evidences of such conflicts. Maybe some day a microscope will be invented

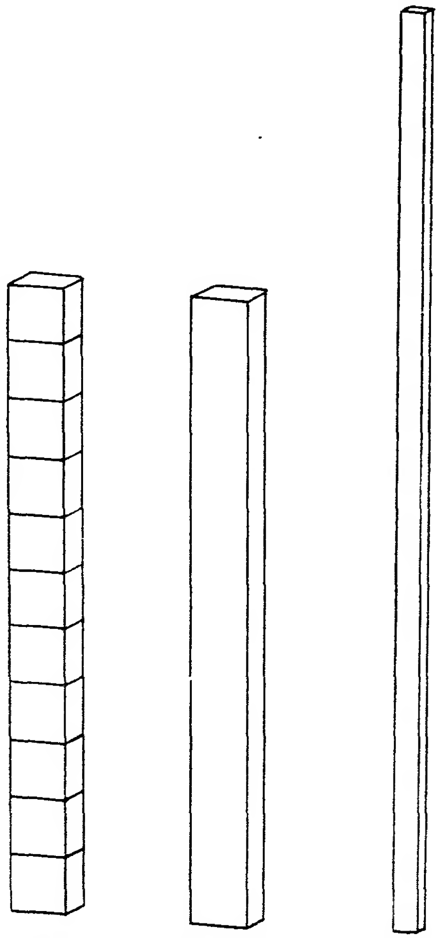


Figure 68 Figure 69 Figure 70

Figures 68–70. Development of Acicular Crystals

powerful enough to make them visible, but until then we can find delight in mental pictures of them.

Flattened crystals. Some curious freaks are produced by the flattening of crystals. Figures 71, 72, 73 will make it clear how an octahedron of pyrite (or of magnetite, or any other isometric mineral)

looks when flattened. The typical octahedron of figure 71 has its faces numbered so that they can be identified as it passes through the slightly flattened form of figure 72 to the very flat form of figure 73.

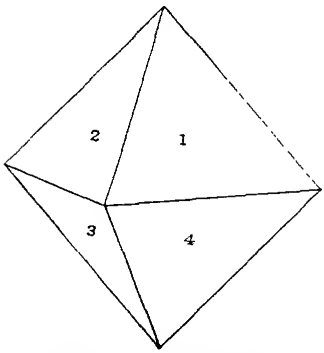
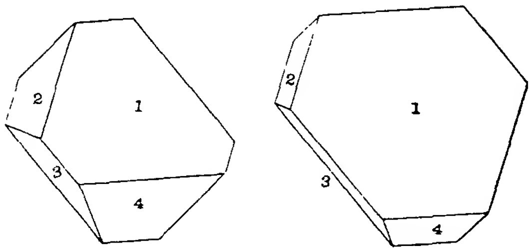


Figure 71. Octahedron



Figures 72, 73. Flattened Octahedrons

Garnet crystals in the form of the dodecahedron, figure 74, are common, but freak crystals like figure 75 are also plentiful. If you ever visit a locality, such as Bodö, Norway, where garnet dodecahedrons are abundant, you will find it most enjoyable to look for these distorted or flattened forms. You will find many gradations from the typical form to those which are very much flattened, and to others which are elongated.

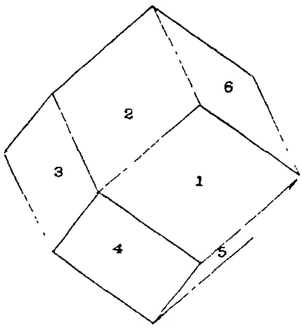


Figure 74. Dodecahedron

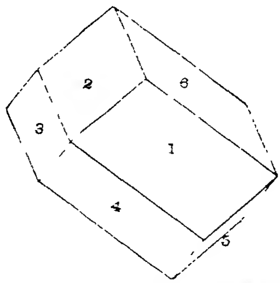


Figure 75 Distorted Dodecahedron

Quartz crystals present many freak forms. It is wise to familiarize ourselves with these for they sometimes look very unlike the typical form shown in figure 76. Figures 77, 78, 79 show some of the results of flattening, while figure 80 shows the result of the equal enlargement of the faces *r* and *z* at the expense of the prism face *m*.

These and the many other distortions of crystals, which are constantly being encountered, are sometimes very perplexing. If it is borne in

mind, however, as already noted, that the angles of crystals do not vary, no matter how much the crystals may be lengthened or flattened, the very perplexities we encounter will stimulate our desire to properly classify the crystals we find.

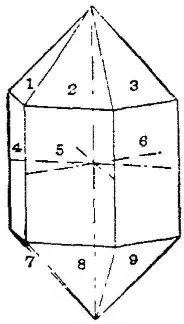


Figure 76

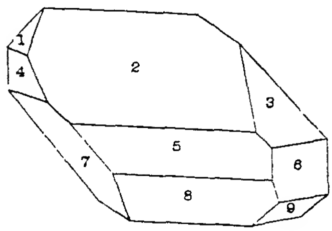


Figure 77

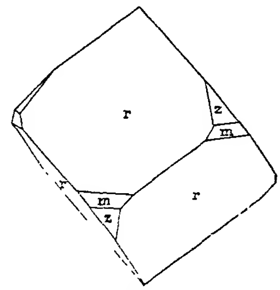


Figure 78

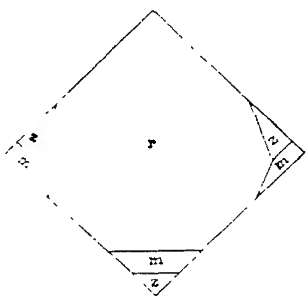


Figure 79

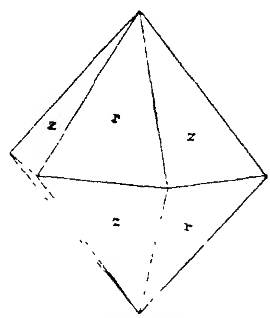


Figure 80

Figures 76–78. Forms of Quartz Crystals, Regular and Distorted
Figures 79, 80. Forms of Distorted Quartz Crystals

Twisted and curved crystals. Every once in a while you will meet crystals which show the effects of forces which tend to twist them out of their normal shapes. Twisted crystals of quartz are common in the St. Gothard region of Switzerland; twisted stibnite crystals are quite common in certain localities, notably near Hollister, California.

Curvature is even more frequently seen, indeed it seems to be the prevailing habit with some minerals and this fact presents a problem for which, it may be, one of the readers of this book may be able to find a solution. Crystals of gypsum frequently show curved faces, or sometimes, as in figure 81, the whole crystal is bent almost double. Crystals of sphalerlite generally have some or all of their faces curved; dolomite is very often found in groups of curved rhombohedrons, figure 198.

Figure 81. Curved Crystals of Selenite

Diamond crystals frequently have their faces curved, as shown in figure 82. A still more wonderful curvature is shown in figure 83, which represents the mineral prochlorite. It very commonly occurs in these curious "worms," which are usually small and are best seen in microscope mounts.

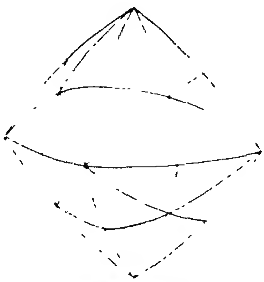


Figure 82

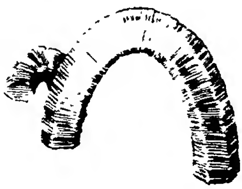


Figure 83

Figures 82, 83. Curved Crystals: 82. Diamond. 83. Prochlorite

Cavernous crystals. Anyone who thinks of crystals as uniform inside, even though irregular outside, will be amazed if he makes it a habit, even for a short time, to hold up to the light and examine with his pocket lens, all of the transparent crystals he meets. He will find that many of them show multitudes of minute cavities. Not infrequently these cavities are filled with a liquid, in which case they cannot be

Figure 84. Bubble in Cavity of Quartz Crystal

readily seen. If they are only partially filled, a bubble will move around in the cavity. Such bubbles may be air, carbon dioxide or some other gas, or simply a vacuum. At times cavities are so large as to be easily seen with the naked eye, as shown in figure 84. Such cavities with movable bubbles are common in selenite and halite, figure 85.

A very remarkable calcite crystal from northern New York, in the collection of the late W. W. Jefferis, had nearly a pint of water enclosed

in a large cavity. Another type of cavity is what is known popularly as a *"negative crystal."* The quartz crystals of Herkimer County, New York and the fluorite of Rosiclare, Illinois, frequently show these empty cavities, which have the form of the typical crystal.

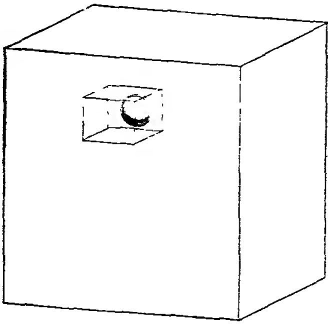


Figure 85

Halite Crystal with Movable Bubble

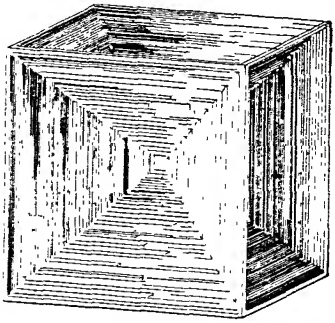


Figure 86

Hopper-shaped Halite Crystal

Crystals which have been formed rapidly are generally more irregular than those which have been formed slowly, the result being that they often have cavities in them. Figure 86 shows a curious, but fairly common, form of salt crystal in which each face is hollowed out, producing a hopper-shaped crystal. Something similar to this in quartz is shown in figure 87.

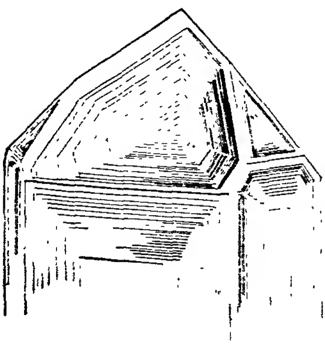


Figure 87

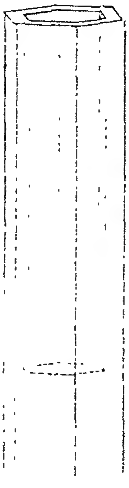


Figure 88

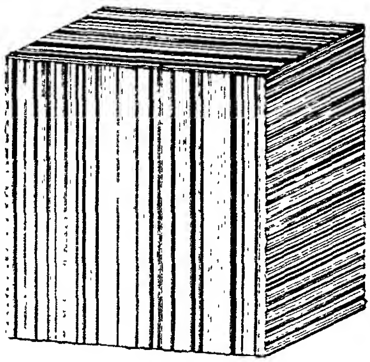


Figure 89

Figures 87–89. 87. Cavernous Quartz Crystal. 88. Cavernous Pyromorphite Crystal
89. Striated Pyrite Crystal

As your knowledge of minerals grows and your collection expands, you will add rarer minerals to it and among these will likely be groups of cavernous crystals of vanadinite, pyromorphite, figure 88, crocoite, and possibly wulfenite and other minerals, and doubtless you will have some minerals of this type which no other collector has. Securing such specimens is one of the incentives to collecting.

Striations. Whenever you go on a hike to a locality in which pyrite crystals occur, be on the lookout for crystals which resemble figure 89. At first sight you would think such crystals were simply marked with parallel lines, but on examining more carefully, you would see that these lines, or striations, are really alternating furrows and ridges and that the tops of the ridges are flat and are parts of the cubical faces of the crystal. The sides of the furrows are alternately parallel with one or

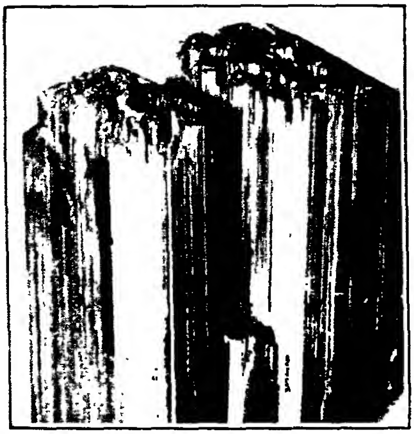


Figure 90. Striated Tourmaline Crystal

the other of two faces of the pyritohedron shown in figure 34. The crystallographer accounts for these furrows and ridges by assuming that when the crystal was forming, there was a conflict between the forces which tended to produce the cube and those that would form the pyritohedron. Each force many times triumphed over the other, only to be defeated by it, and so victory swung from one side to the other. Because the Latin word for *swing* is *oscillum*, he calls the resulting combination of faces an "*oscillatory combination.*" We have the record of the struggle preserved in this wonderful striated crystal. Thousands of these striated crystals of pyrite and many more thousands of striated crystals of other minerals, in which other faces are similarly developed, bear testimony to conflicts silently waged during millions of years in the mineral kingdom and preserved for our study all over the world.

Tourmaline crystals often furnish excellent illustrations of striations. The prismatic faces may be so deeply striated that it is impossible to distinguish any faces at all, as shown in figure 90.

Horizontal striations on quartz crystals, figure 91, are very common and show most excellently the oscillation between the prism and the terminal rhombohedron.

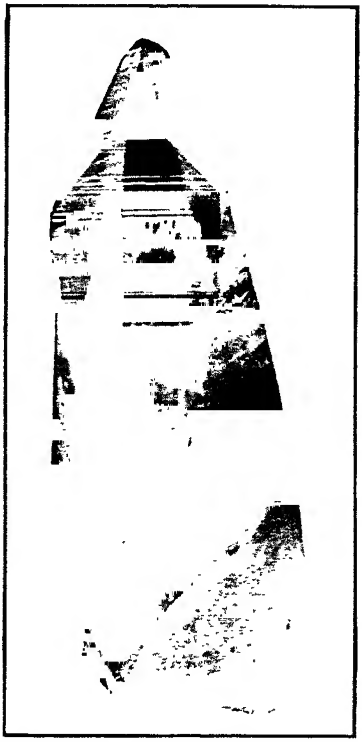


Figure 91. Striated Quartz Crystal

Without some knowledge of striations, the student might be puzzled to account for the deeply ribbed tourmaline prisms and other transformed faces of crystals, but what a new interest he has in such forms when he sees in them the records of battles fought millions of years ago.

The collector who keeps his eye open for curiously shaped crystals will eventually be able to find a great variety of interesting freaks, but do not expect to pick up many kinds quickly. Some of them will be readily secured, but most of them will come one by one and be prizes to reward the keenness of the diligent collector.

Chapter 12

HOW AND WHERE CRYSTALS OCCUR

We are starting out scouting for crystals! How shall we find them? Crystals are usually found in one of three ways: First, loose in a cavity in the rock in which they were formed; second, attached to the rock or to a mass of the same or to some other mineral; third, embedded in the rock.

The quartz crystals of Herkimer County, New York are generally loose in cavities of siliceous limestone; the selenite crystals of Ellsworth, Ohio, occur embedded in clay, figure 92.

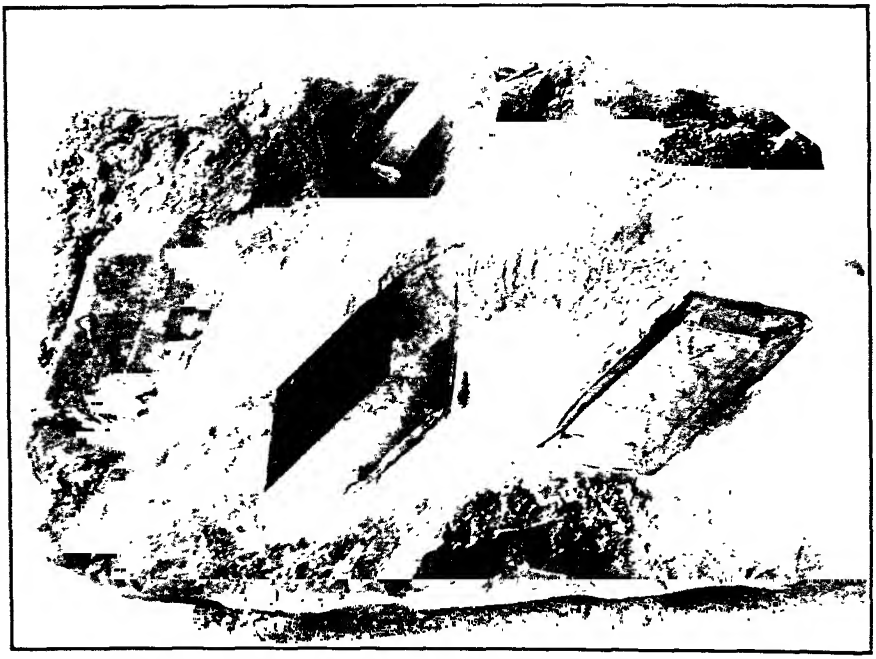


Figure 92. Selenite Crystals Embedded in Clay, Ellsworth, Ohio

Near Hot Springs, Arkansas, quartz occurs in clusters of beautiful, attached crystals, as shown in figure 93. Groups of quartz crystals are very common in many other localities. Usually they branch out from each other very irregularly.

In the vicinity of Joplin, Missouri, there are caves completely lined with great crystals of calcite, some of them weighing as much as one hundred pounds, figure 94. It is an inspiring sight to stand in such a

Figure 93. Attached Crystals of Quartz, near Hot Springs, Arkansas

cave and see these marvelous creations of nature, the points of the crystals clear and perfect and glittering all around us. Such a cave, found about the beginning of the present century, yielded many hun-

Figure 94. Group of Golden Calcite Crystals from Joplin, Missouri, in American Museum of Natural History. Weight, Approximately 100 lbs.

dreds of the most gloriously beautiful golden calcite crystals ever found. You can see them in many large museums. What a thrill it gives us to collect minerals in a locality like this! Yet there are many places, all over the world, in which wonderful groups of crystals may be had.

Parallel grouping. Figure 95 shows a group of crystals of the amethyst variety of quartz arranged in parallel position. Standing

Figure 95. Amethyst Crystals in Parallel Position, Jefferson County, Montana

with our backs to the light we catch the reflection of the light from the same face of every crystal in the group. You will very likely find similar specimens if you visit the Little Pipestone District in Montana, and they occur also in a good many other localities.

In Colorado, England, and elsewhere, octahedrons of fluorite are found built up of small cubes all in parallel position, as shown in figure 96. This is a very remarkable illustration of the combination of the crystallizing forces, one of which produces little cubes while another arranges them in the form of an octahedron.

Arborescent or tree-like grouping. One of the most beautiful groupings of crystals is that which may often be seen on the window pane or the sidewalk on a frosty day. These charming forms, with their

delicate tracery and tree-like shapes, are arborescent groups of ice crystals. Such natural beauties are sometimes seen in gold, silver, and copper, especially in minute crystals suitable for box mounts for the microscope.

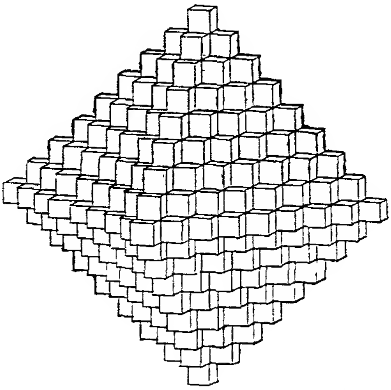


Figure 96. Model of Fluorite Octahedron Built up of Cubes

Reticulated grouping. The Latin word *reticulatus* means "*made like a net,*" so the mineralogist calls such a grouping as that of cerussite, shown in figure 97, a reticulated grouping. It is frequently seen in

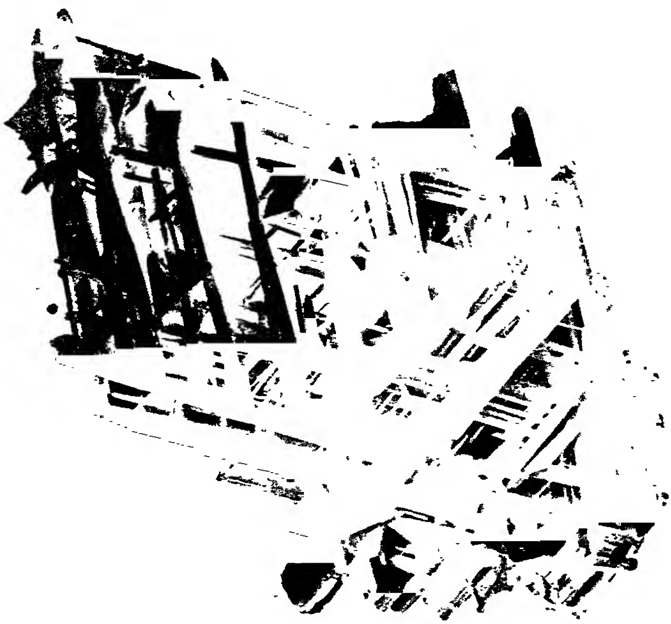


Figure 97. Reticulated Grouping of Cerussite Crystals

cerussite and it often aids in distinguishing this mineral from anglesite, which it closely resembles. Rutile is also found in similar reticulated groups of crystals.

Rosettes. The commonest of all the iron ores is hematite. Strange as it may seem, this mineral sometimes groups its crystals around a common center, producing a form somewhat like a rose, figure 98, thus

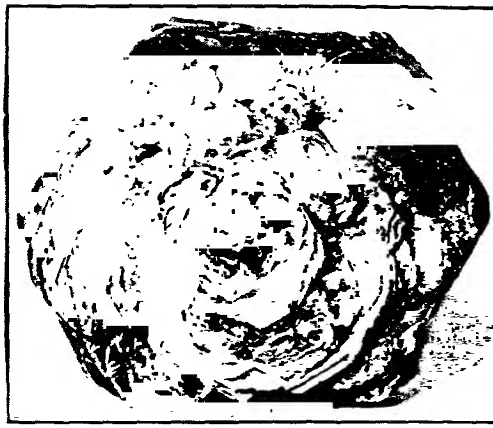


Figure 98. Rosette of Hematite ("Iron Rose"), St. Gothard, Switzerland

giving rise to the popular name of "iron rose." Rosettes of barite, gypsum (figure 190), and other minerals have been called "desert roses."

Drusy grouping. Did you ever visit Globe, Arizona, or see in the Colorado tourist stores specimens of so-called "blue quartz"? What a charming color they have and how they sparkle as the light is reflected from the faces of multitudes of tiny crystals which coat the surface of robin's-egg blue chrysocolla! Such densely grouped crystals when small, are called *drusy*. Drusy quartz is of common occurrence, and you will see this method of grouping illustrated in other minerals as well.

Twins. Surely there are no twins among minerals! Yes, indeed there are and many of them are just as firmly joined together as were the famous "Siamese twins." Twins are sure to be met by every collector who does much field collecting or who visits a good museum. In the mineral staurolite, twins like figures 100, 101, are even commoner than single crystals, figure 99. Twins of calcite, page 149, and of feldspar, page 222, abound in some localities and are of many different forms.

Let us make a model of a twin of diamond. First make an octahedron

from a potato, as described on page 43. Next look at figure 102 and then mark with your knife the centers of the edges *ab* and *ac* on the upper half of the model, the centers of the edges *de* and *ef* on the lower half, and the center of the edges *dc* and *bf* on the middle of the model. Then cut the model into two equal parts as indicated by the plane *hglkjih* in

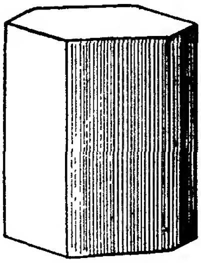


Figure 99

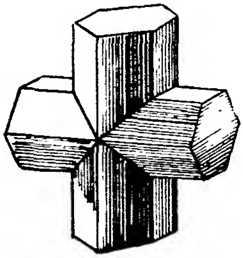


Figure 100

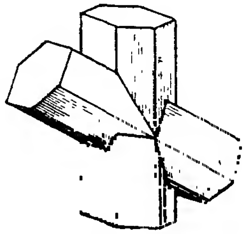


Figure 101

Figures 99–101. Staurolite: Single Crystal and Two Twins

the figure. When you have cut the model in half in this way, hold the cut surfaces of the two pieces firmly together and revolve one on the other through half a circle (180°). You have thus formed a model of an octahedral twin, figure 103, which is the simplest illustration of twinning. This is a common form with the minerals diamond, spinel

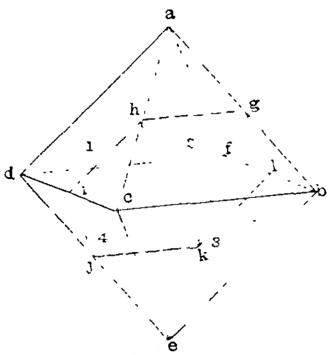


Figure 102

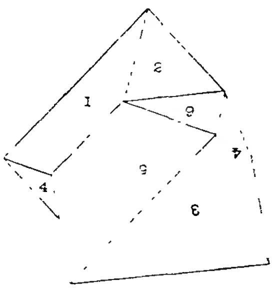


Figure 103

Figures 102, 103. Development of Octahedral Twin

and magnetite and the form is known as a "spinel twin." After making this model we can easily understand that the difference between the octahedron and the twin is that in the twin one half of the octahedron is in a position exactly reversed in relation to the other half. Notice also that the cut surface is parallel to one of the faces of the octahedron This surface is known as the "twinning plane."

Sometimes we see crystals which appear to be compounded of two whole crystals instead of two halves. Figure 104 is an illustration of one of the so-called "penetration twins" of fluorite which are common in England and many other localities. You see this is really two cubes penetrating each other and not two halves of a single crystal.

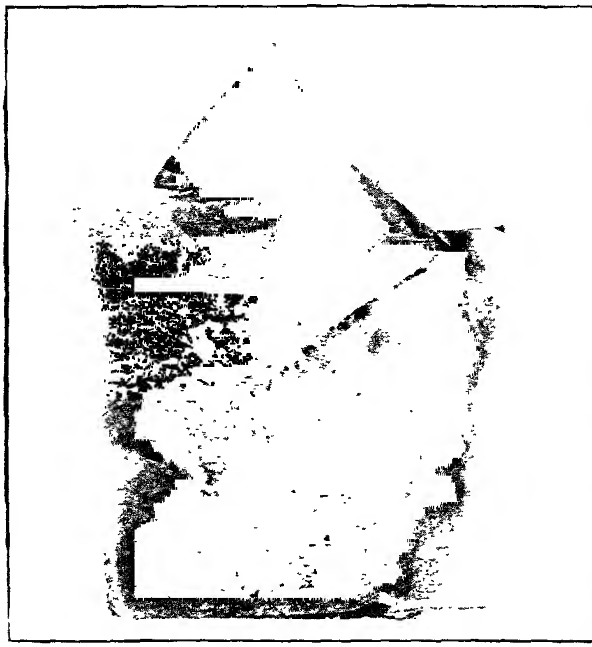


Figure 104. Penetration Twin of Fluorite Cubes, England

We have now learned that *in a twin, one of the halves of a single crystal, or one of two whole crystals, appears in a position exactly reversed in reference to the other half or to the other crystal, as though it had been revolved exactly a half circle or 180°.*

Figure 105. Twinning Striations of Oligoclase Feldspar

Some minerals very frequently occur in twins, while others never do. They are, perhaps, more abundant and more varied in the great group of the feldspars than among any other common minerals.

Many twins are very complex and difficult to understand, but if we keep the picture in our mind of that half-circle revolution of one part on the other, it will be surprising how many twin crystals we will recognize, even though we may not always be able to explain them.

Twinning shows itself in the plagioclase group of feldspars by striations. These are sometimes very coarse, as in albite, while in oligoclase, figure 105, they are fine, and in microcline they are practically microscopic.

You will find this elementary knowledge of twinning a great help to you in identifying minerals and, eventually, when you study the subject more deeply and see twin crystals of many minerals, often of great beauty and with hosts of sparkling faces, you will realize what a fascinating field for study you have entered.

Chapter 13

HOW MINERALS BREAK—CLEAVAGE AND FRACTURE

1. CLEAVAGE

The best way to understand how minerals break is to break them, but you will find it wise to secure by purchase some thoroughly typical material, as advised in chapter 3. It is surprising how much can be learned if you have such material and a small hammer. If possible, get a little group of collectors together and study this subject with them and you will find it well worth while and most interesting.

Cleavage is the tendency of certain crystals to break in definite directions. The break is always parallel with the faces of one of the simple forms of the crystal system to which the crystal belongs; thus isometric crystals cleave parallel with the cube, octahedron or dodecahedron; tetragonal crystals cleave parallel with the base, the prism or the pyramid, and so on. After you have become acquainted with these simple forms by the study of chapters eight, nine and ten, the property of cleavage will be most interesting.

It is natural to wonder why the cleavage is parallel with a simple face. X-ray studies have shown that the atoms of which the crystal is built, are crowded densely in these simple planes and that between them there is relatively more space, thus creating planes of weakness. It has also been shown that this crowding of the atoms is not the only factor which decides the direction of the cleavage, for diamond cleavages are octahedral and sphalerite dodecahedral, notwithstanding the fact that the internal structure of their crystals is identical. It is probable that there is a difference in the electrical attractions between the layers of atoms which has an influence in determining the direction of cleavage. However this may be, we know that the kind of cleavage which many minerals usually have is a very great help in identifying them and in distinguishing them from certain other minerals.

The property of cleavage is, fortunately, well illustrated among the common minerals, though we must bear in mind that some of these minerals also occur in granular forms or those which show but little, if any, cleavage. You can be sure, however, that if a mineral shows cleavage at all, it will be developed by breaking a pure, unaltered crystal of it.

Let us take a small hammer with a sharp edge and strike a piece of halite from Stassfurt, Germany, a sharp, quick blow. See! It breaks into many little cubes, but very frequently instead of being simple cubes,

the cleavage extends in the cubical directions for a little distance, then there is an offset at right angles to the first direction, or, maybe, many offsets, then it finishes either in the original direction or at right angles. This is well shown in figure 106. While this tendency to produce offsets makes it difficult to secure perfect cubes, it really aids us in understanding the property of cleavage, for it shows that the tendency of the mineral to cleave is so strong that it will not break far in one direction before the forces tending to produce the cube compel breakage in the other two directions required to finish the cube.

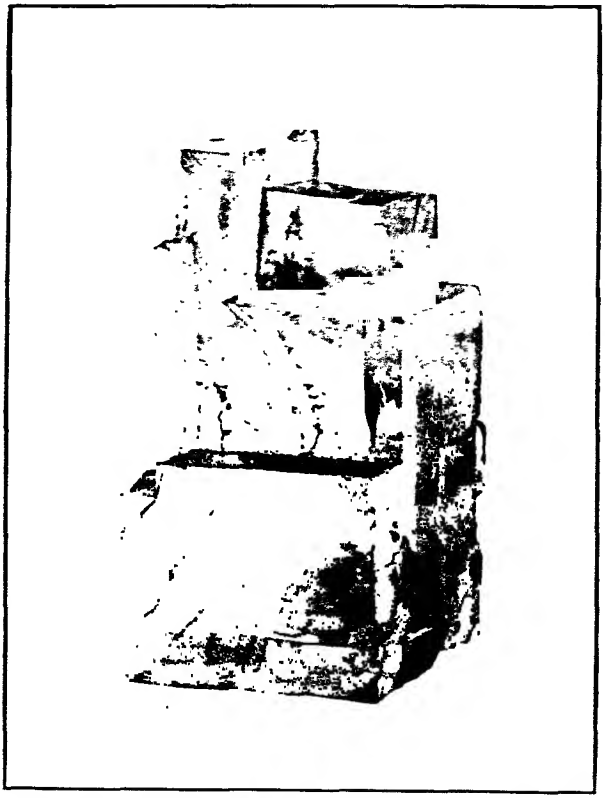


Figure 106. Cubical Cleavage of Halite, Showing Offsets

With care, however, we may secure quite perfect cleavages from good material; indeed in some minerals it is really difficult for a beginner to distinguish such "cleavage crystals" from true, natural crystals. Bear in mind, however, that cleavages are apt to have rougher faces than natural crystals and can usually be distinguished by that fact.

It is very interesting to cleave fluorite, and, with a little practice, quite regular octahedrons may be obtained from good material. A visit

to the fluorspar mines of southern Illinois will yield an abundance of good material, or it may be bought by weight from a dealer. As you break it up, you will be amazed to see what a variety of forms you will secure. Incidentally, they will serve as excellent illustrations of the disguising of the crystal form by distortion. A series of the forms, some of which you will be very sure to break out, is shown in figure 107.

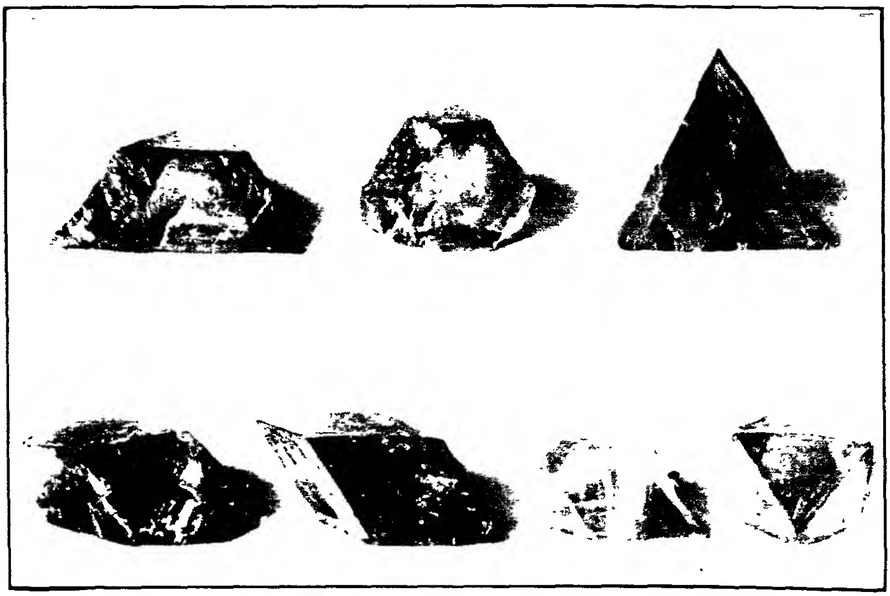


Figure 107. Cleavages of Fluorite, Westmoreland, New Hampshire

Sphalerite has a dodecahedral cleavage, but it takes considerable skill and extra good material to secure anything approaching a perfect cleavage dodecahedron, figure 108. It is not difficult, however, to develop the cleavage sufficiently to show at least three faces and consequently the angles of the dodecahedron.

So far we have cleaved only isometric minerals, but cleavage is none the less strikingly developed in other systems. Calcite furnishes as good an illustration as there is of the property of cleavage. We have already made its acquaintance in studying about rhombohedral crystals, page 54, and we learned that its crystals are often highly complex externally. Notwithstanding this fact, they always cleave into simple rhombs, figure 109. This is one of the most distinguishing properties of calcite and we should, therefore, impress it on our memories. No matter how small we break crystallized calcite, it continues to break into rhombs, though, of course, we must not expect perfection, for we will have distortion in the cleavages of calcite, as in other minerals, and also the

same tendency to multiply its cleavage by offsets, figure 110. Bearing in mind that quartz has practically no cleavage, it is easy to tell it from calcite.

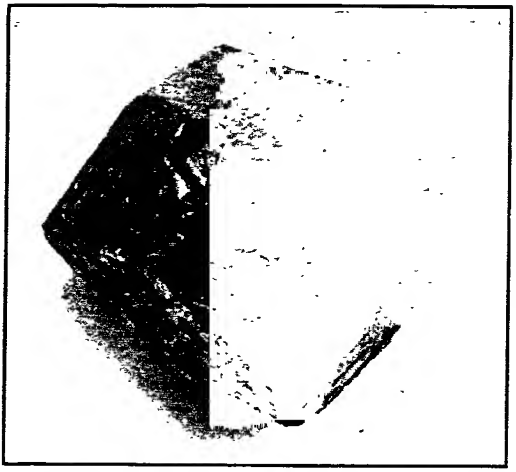
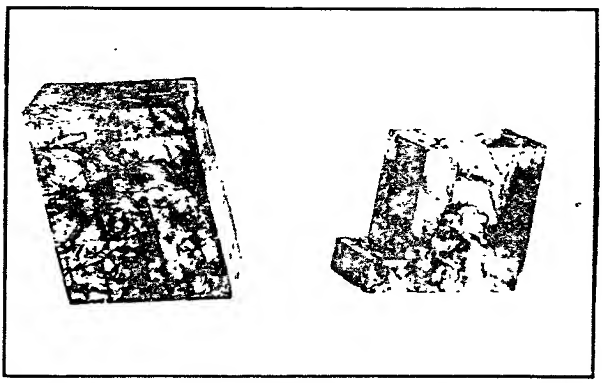


Figure 108. Dodecahedral Cleavage of Sphalerite, near Joplin, Missouri

Common feldspar generally shows two cleavages nearly at right angles to each other, while cleavage in the third direction is only very crudely developed, so that regular crystal forms cannot be obtained. It is pos-



Figures 109, 110. Rhombohedral Cleavages of Calcite

sible, however, to split off quite thin plates, figure 111. The angles between their respective cleavages serve to distinguish calcite and feldspar.

In mica the cleavage is so remarkably developed in one direction that plates thinner than tissue paper can readily be separated. This is the most remarkable characteristic of the great group of micas, which are so abundant in many rocks that you will have no difficulty in securing

pieces of mica with which to experiment. Such cleavage, in whatever mineral it occurs, is spoken of as *micaceous.* This cleavage is always parallel with the base of the crystal and is consequently also called *basal.* Basal cleavage is frequently seen in minerals such as topaz and apophyllite, which cannot be split into thin sheets, but which do split readily parallel with their bases.

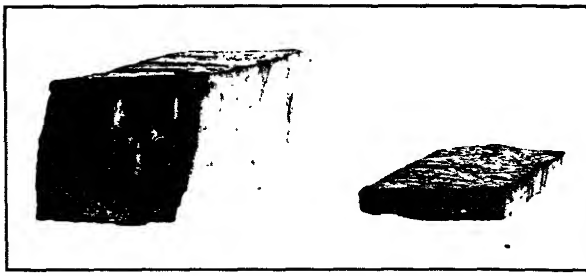


Figure 111. Right-angle Cleavages of Common Feldspar

Selenite, which we have seen (page 51) is a monoclinic mineral, has a very easy cleavage parallel with the side faces of the crystal and it is possible to split off quite thin sheets, the same as with mica, but the process cannot be carried nearly as far as with mica, because the cleavage is not nearly as perfect.

A comparison of amphibole and pyroxene furnishes one of the best possible illustrations of the importance of cleavage as an aid in identifying minerals which often closely resemble each other. These are two of the most important and abundant of the rock-forming minerals. Amphibole has a prismatic cleavage, the angle between the two adjoining cleavage faces being just about that of a regular hexagonal prism, actually 124°. Pyroxene has only indistinct cleavage, but it frequently shows a "parting" which is easily mistaken for cleavage. The angle between the adjoining faces of its prism is very nearly a right angle, actually 93°. It is often possible, even in rock specimens, to see the cleavage distinctly by the aid of a pocket lens, and thus distinguish between amphibole and pyroxene.

A lack of cleavage is sometimes a good guide in identifying minerals, thus black tourmaline is easily distinguished from cleavable amphibole and pyroxene, and quartz is distinguished from cleavable calcite. If we see a mineral with a good rhombohedral cleavage, we *know* that it is not quartz, without making any further tests, for quartz does not cleave into rhombs.

Keep your eyes open for cleavage and you may surprise some expert mineralogist sometime when he is off his guard and is not observing as

carefully as he should. Possibly he may call feldspar, calcite and your knowledge of cleavage will enable you to show him the error. Certainly cleaving minerals should furnish some real entertainment and make the study of mineralogy easier and more fascinating.

2. FRACTURE

The break of minerals other than cleavage is called fracture.

Fracture is not confined to those minerals which do not have cleavage, but it is generally difficult to break a cleavable mineral so as to show its fracture. For this reason it may be safely doubted whether one mineralogist in ten has ever seen the fracture of calcite.

The most striking illustration of fracture is presented by those minerals, and some rocks, which have what is called *conchoidal* fracture. This word is derived from the Greek *konche*, a *shell*, and *eidos*, *form*. Conchoidal fracture is, therefore, a kind of break resembling a shell. One of its best illustrations is the volcanic glass, obsidian, figure 112.

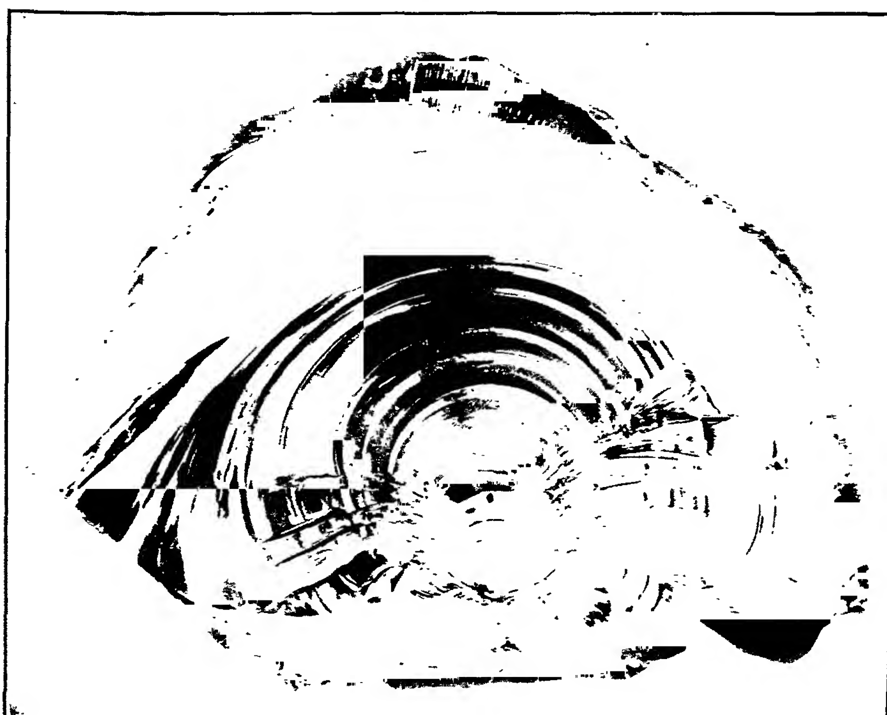


Figure 112. Conchoidal Fracture of Obsidian, Lipari Islands, Italy

When the fracture approaches conchoidal, but is not very distinctly developed, it is called *sub-conchoidal*. Many of the varieties of quartz

show this kind of fracture, but sometimes, in well crystallized specimens, a true conchoidal fracture is seen. Examine a piece of flint and see which kind of fracture you think it has.

Some of the other varieties of quartz, such as jasper, do not show any regularity in their break and are said to have an *uneven* fracture.

Did you ever draw your finger across a piece of the common copper ore from the famous Calumet and Hecla Mine in the Lake Superior region of Michigan? If you do so, you will find that the surface is very jagged. This same rough feel would be produced in a mass of copper if you were to hack it with an axe, and for that reason this type of fracture is called *hackly*.

Importance of Cleavage and Fracture

While fracture is not a property of first importance, cleavage is, and it is well to remember, in identifying minerals, that the clear exhibition of a property should influence us more than the failure to exhibit the property. For example, the finding of a good rhombohedral cleavage is a much stronger argument in favor of calling a mineral calcite than the failure to secure a conchoidal fracture would be an argument against its being calcite, for cleavage is a much more constant and important property than fracture.

Chapter 14

THE WONDERFUL STRUCTURE OF MINERALS

In our study of crystals we looked both at their external forms and at the forces which held their particles together, and we saw that these forces are exerted in definite directions. If we strike a crystal of quartz a sharp blow with a hammer, we find that it has no distinct cleavage. If we continue to break it up until we secure a fragment which shows no trace of a crystal face, it could still be proved by the expert mineralogist or by the physicist that this fragment was really a part of a crystal and not simply a formless mass. He could even determine the position of the axes of the former crystal. These results would be attained by certain processes of etching with acids, by which the internal structure of the crystal would be revealed. If he were to cut a very thin slice of the mineral and examine it under a properly equipped microscope, he could prove in this way also that the mass was a part of a crystal and possessed an internal structure.

This great field for research lies before anyone who is not content with learning only a little about minerals, but who realizes that their earnest study offers him a life work full of pleasure and profit.

In chapter seven we took a brief look at ice crystals forming in a pool of water. If we look long enough we will see that the great sheet of solid ice was formed by one crystal after another forming until there were so many and they grew so large that they interfered one with another, until at last the water had all crystallized and become a solid mass of crystals. Professor Tyndall devised a very beautiful experiment to prove that while the crystals of ice cannot ordinarily be seen in the mass, they are there just the same. Figure 113 is his picture of what he saw.

If we had Professor Tyndall's eyes and his ability and equipment, we could picture the inside of other crystal masses and behold their beautiful structure, yet the mineralogists of today have discovered far greater wonders in crystals than Professor Tyndall ever dreamed existed in them. Such advanced studies, however, require expensive apparatus and knowledge which it takes years to acquire. Some of us may, later on, be privileged to enter these Elysian fields, but most of us must content ourselves with looking at the external evidences of the structure of minerals and the varying ways in which they are aggregated into solid masses.

Visit a marble quarry, or if none is near you, a marble cutter's yard. Pick up a piece of marble and examine it with your pocket lens. You

will see at once that it sparkles by the reflection of light from many small, smooth surfaces, which look to us like faces of crystals or of cleavages. These were produced by the effort of the mineral to crystallize. The great pressure to which the mineral was subjected when it was forming, and the lack of room prevented its producing distinct crystals, just as in the case of the solid ice, but its tendency to crystallize was so strong that it could not be completely overcome. The result is that the whole mass of the marble is full of minute crystal or cleavage faces.

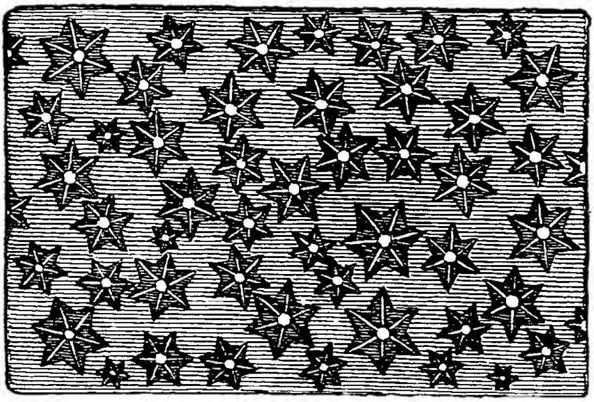


Figure 113. Ice Crystals in Mass of Ice; after Professor Tyndall

A mineral in which the tendency to crystallize is evident, but in which no distinct crystals are to be seen, is called crystalline. Marble is an excellent illustration of a crystalline mineral and it shows that the crystallizing forces operate down to very minute particles.

While the great majority of minerals have a crystalline structure, there are many different types of these crystal aggregates and it is with these, even more largely than with the distinct crystals, that the collector will most frequently come in contact. While they lack, in most cases, the great beauty of the crystals, they will well repay study.

A mineral which is composed of aggregates of grains is called *granular,* or is said to have a *granular structure.* The size of the individual grains varies very much and marble is a good illustration of several of the types; thus we have the *coarse granular* marbles of Georgia and the *fine granular* marbles of Vermont and of Carrara, Italy.

In lithographic limestone and chalk the grains are so exceedingly small as to disguise the granular structure almost completely. Such varieties are called *compact.* At the other extreme we find some limestones with grains several inches across.

If the grains are loosely held together, so that the mass crumbles

readily, it is called *friable.* Sandstone from Klondike, Missouri, is a good example.

Some minerals are built up of plates, or "laminae," and such minerals are said to be *laminated,* or to have a *lamellar structure,* as in the variety of albite called cleavelandite. If these plates or leaves can be separated from one another, the mineral is called *foliated.* Talc and

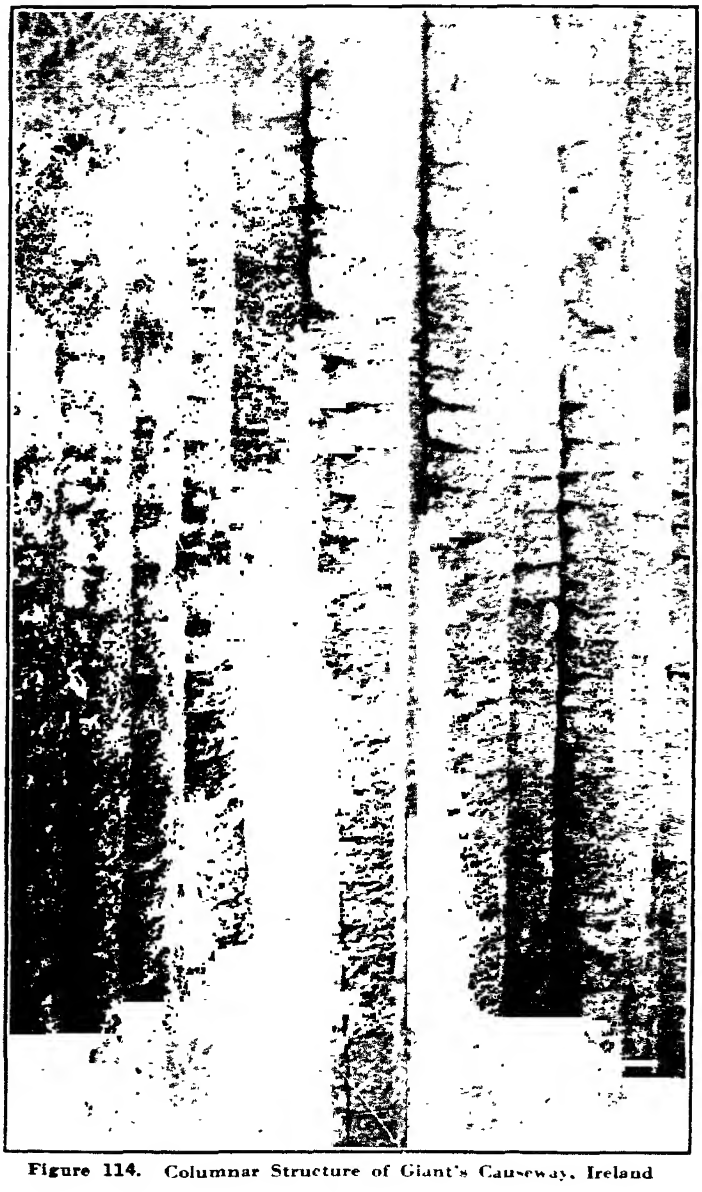


Figure 114. Columnar Structure of Giant's Causeway, Ireland

graphite are good illustrations. When very thin sheets can be separated. as we have seen on page 79 can be done with mica, the mineral is called *micaceous,* or is said to possess *micaceous structure.*

Doubtless you have seen pictures of the Giant's Causeway in Ireland, a small section of which is shown in figure 114. What a wonderful

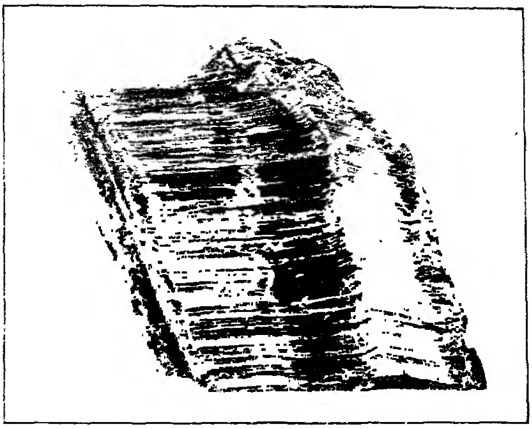
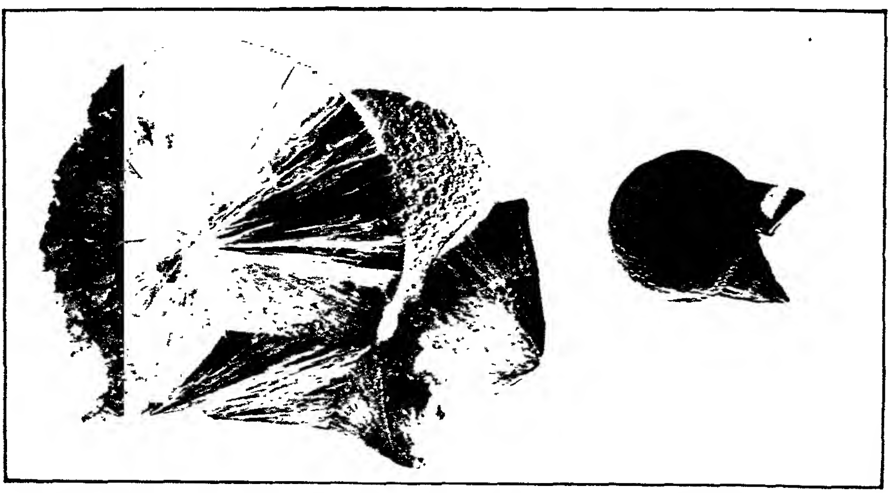


Figure 115. Fibrous Structure of Crocidolite, South Africa

sight it is with its huge six-sided columns. There are formations similar to this in many parts of the world. Such a structure is called *columnar.* We naturally think of a column as something large, so this name is confined to structures of considerable size.



Figures 116, 117. Radiated-Fibrous Structure and Globular Form of Pectolite, Paterson, New Jersey

A flattened, columnar structure, such as is seen in the mineral kyanite, is called *bladed.*

When the columns are small they are no longer spoken of as columns, but fibers. A mineral made up of many little fibers is called *fibrous.* An excellent illustration of this structure is asbestos. Figure 115 shows the South African "blue asbestos," or crocidolite. The Canadian asbestos has such a fine-fibrous structure that it is possible to weave a strong fabric out of its fibers, just as is done with cotton or silk.

Occasionally the fibers of a mineral radiate from a common center, as in pectolite, figure 116. It is natural to call such a mineral *radiated.* The ideal radiated mineral is one which is completely spherical, with the fibers all radiating from a common center. Pectolite is found in such radiated balls, as shown in figure 117. Such an occurrence is called *globular.*

Some radiated minerals are made up of entire crystals with terminations on the outside. This is frequently the case with the beautiful groups of amethyst from Uruguay, also in stibnite from Roumania, figure 118, and aragonite from England, figure 183.

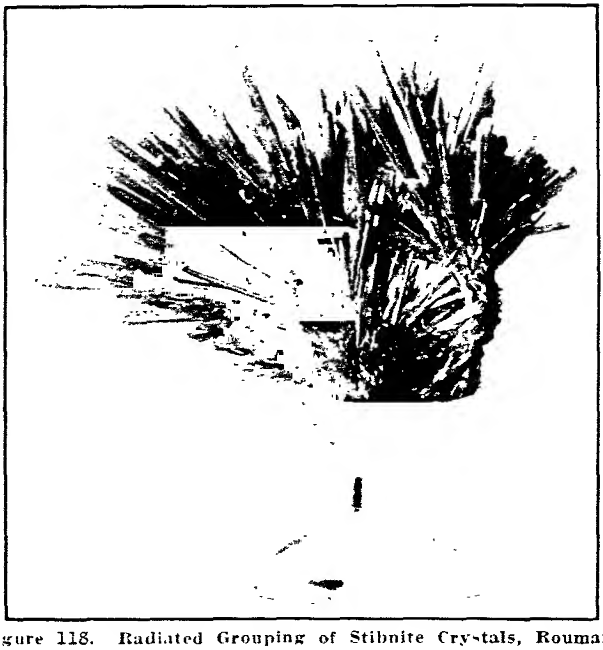


Figure 118. Radiated Grouping of Stibnite Crystals, Roumania

As we meet these and other varieties of structure in minerals, we cannot fail to be impressed with the fact that the more we study the mineral kingdom, the richer will be the rewards which we will receive.

Chapter 15

MINERAL MIMICS

We would not expect to find mimics in the mineral kingdom, but they are actually very abundant. Does not figure 119 look very much like a kidney, yet it is actually a photograph of a variety of hematite iron ore from England, which very naturally has been given the name of

Figure 119. "Kidney Ore," Cumberland, England

"kidney ore." It was formerly abundant in the English iron mines and specimens of large size were even more plentiful than small ones. It is sometimes seen in the Lake Superior iron mines. Malachite one of the copper ores, frequently is found in such specimens as figure 120.

If we were to break such specimens of hematite and malachite, we would probably find quite a difference in their internal structure. The hematite would most likely show a distinctly radiated-fibrous structure, while the malachite would probably be curved-lamellar. If we were to polish sections of the two minerals at right angles to any portion of the surface, we would see this difference very distinctly. The fibers of the hematite radiate from the center of the kidney, while the layers of malachite often circle around parallel with the surface, very much like the beautiful Brazilian agates, figure 121, exhibiting what is known as *concentric structure*.

What a good mimic of a bunch of grapes we see in figure 122, which shows a specimen of hematite. Because the Greek word, *botry*, means

Figure 120. Kidney-shaped Malachite, with Curved-Lamellar Structure, Bisbee, Arizona

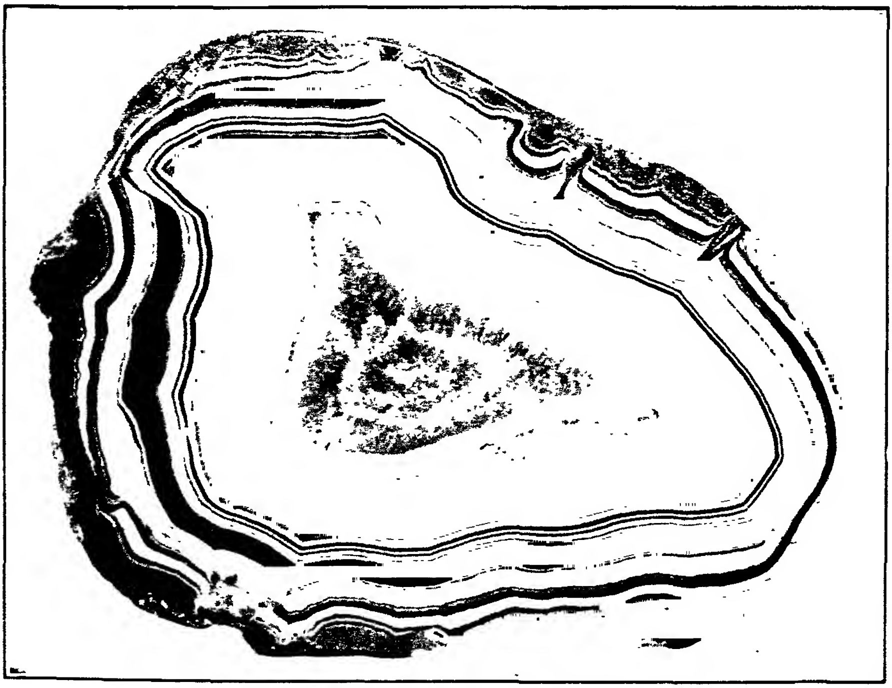


Figure 121. Agate showing Concentric Structure, Brazil

Figure 122. Botryoidal Hematite, Michigan; Collection of Michigan College of Mines

cluster, and *eidos*, means *form*, mineralogists call a form which resembles a cluster of grapes a *botryoidal form*. If you happen to live in a region in which the chalcedony variety of quartz is found, it is quite possible that you will find specimens of this grape-like form, figure 123. There are many other minerals which show it, though it is difficult to

Figure 123. Chalcedony in Grape-like Form, Colorado. Courtesy of Ward's Natural Science Establishment, Inc.

find thoroughly typical specimens. Watch out for it when you visit iron mines in which limonite is found.

When you visit a region where diabase or other basaltic rocks are found, be alert for masses filled with holes. Maybe it will seem odd to you to think of filling a solid mass with nothing! Before these rocks were solidified, these holes were formed by the expansion of steam. Later on many of them were filled with many beautiful minerals, chiefly the group known as zeolites, about which we shall learn more later. (page 246). While the holes are often quite round, many large masses of rock in many places are full of holes which are almond-shaped, and

Figure 124. Coralloidal Form of Aragonite, Styria.
Courtesy of J. G. Manchester

for this reason and because the Greek word *amygdale* means *almond*, this structure is called *amygdaloidal*.

In some iron mines and caves the mineral aragonite produces an odd form which mimics the branching corals so well that it is called *coralloidal*. A specimen is shown in figure 124, but there is an almost endless variation in the appearance of such specimens.

You may believe it or not, but there are places where minerals mimic peas. If you visit the hot springs at Carlsbad, Bohemia, you will find there deposits of "pea-stone" or "pisolite," figure 125, made up of great

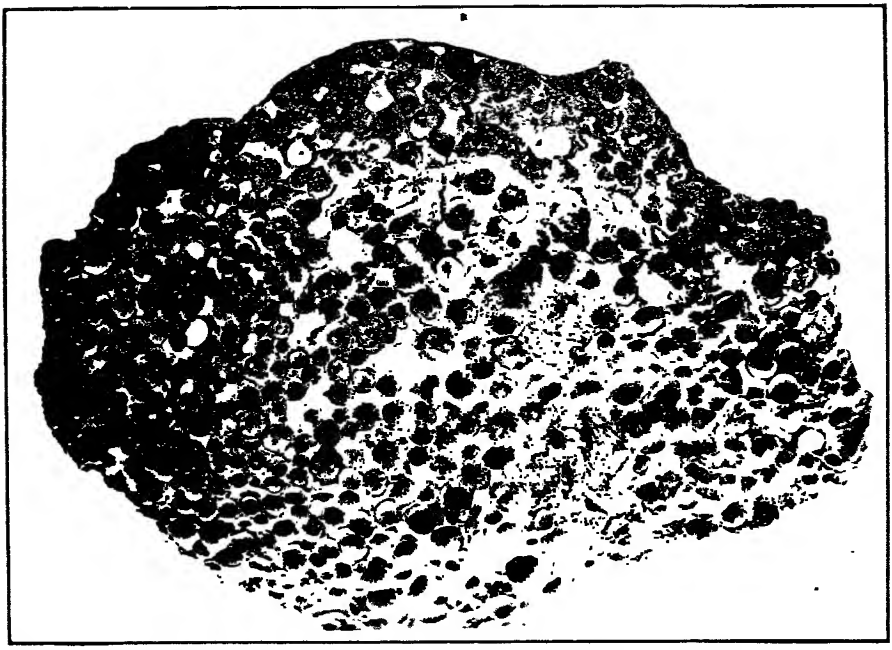


Figure 125. Pea-like Form of Pisolite, Carlsbad, Bohemia

numbers of quite perfect spheres about the size of peas. These are loosely cemented together by the same material, but if you break a piece, a number of the "peas" will fall out and roll away, as peas do when they are being shelled. The Latin word *pisum* means a pea, so mineralogists call this kind of formation, "*pisolitic*." The common ore, bauxite, very frequently occurs in pisolitic masses and occasionally limonite, one of the common iron ores, is pisolitic. Figure 126 shows some less perfect "peas" forming "bird's nest calcite."

If we were to cut one of the little "peas" through the center, we would find that it is made up of many layers of the mineral deposited concentrically around the center. Usually a grain of sand or some other

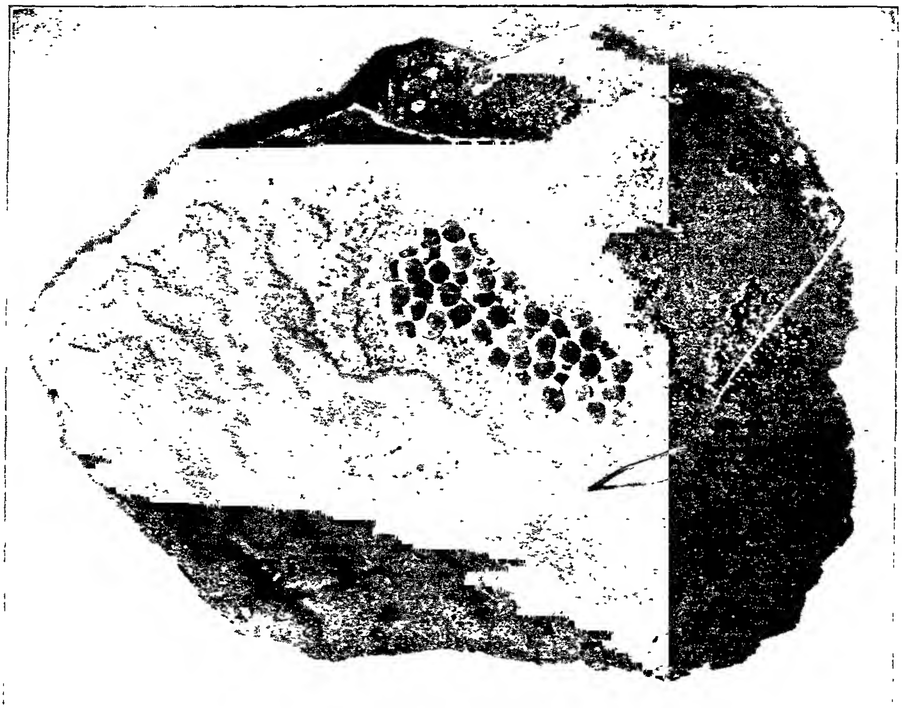
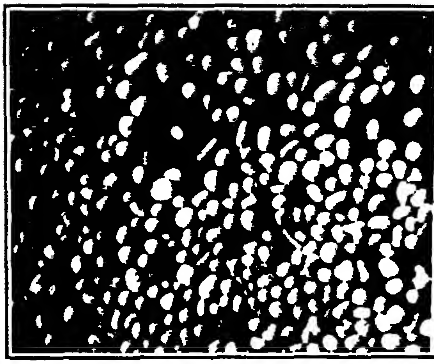


Figure 126. "Bird's Nest Calcite," Reichelsdorf, Hessen, Germany

object forms the nucleus. A formation produced by the deposit of mineral matter around a center is called a *concretion*, and the structure is called *concretionary*.

Have you ever examined any shad roe? How well it is mimicked by the mineral oolite, so called from the Greek words *oon*, an *egg and lithos, stone*. Do not get the idea, as some have, that this "egg-stone" or oolite is really a petrified shad's roe. Oolite is simply a mass of small concretions, the same as pisolite except that they are smaller. Ask an architect to point out to you a light gray, or maybe a cream-color building made of Indiana limestone. You will see in it multitudes of these little mineral eggs. If you happen to be in England, you will soon find a building made of "Portland Stone" which is a still better illustration of oolite. As vast beds of oolitic limestone exist in many places, the number of complete concretions in nature is inconceivably large.

Along the shores of the Great Salt Lake, Utah, there are beds of sand composed of minute oolitic concretions. Figure 127 shows this sand magnified, while figure 128 shows the concretions ground down and magnified so as to show their internal structure and the nuclei about which they have formed. We do not, however, have to travel to the



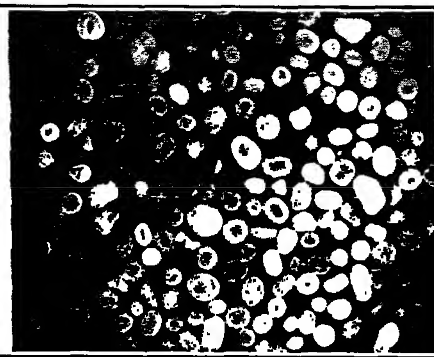


Figure 127. Oolitic Sand, Great Salt Lake, Utah. Figure 128. Same, Ground Down

ends of the earth to see these marvels of the mineral kingdom, for even the builders bring them from far away and make our office buildings of them.

Figure 129 shows a mineral mimic of raindrops. These tiny spheres, which are greatly magnified in our picture, are hyalite, a variety of opal, from Japan. The mineralogist would speak of such an occurrence

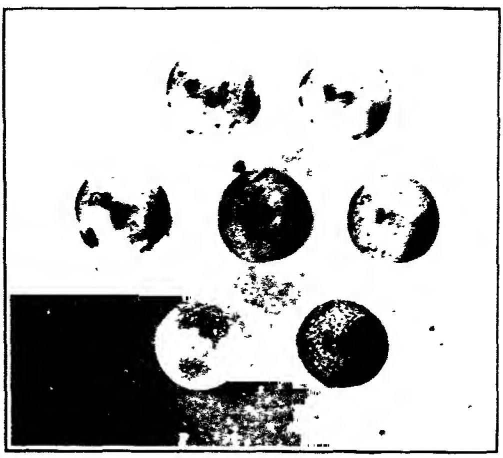


Figure 129. Globular Hyalite, Japan

as globular, but these globules are different from the sphere of pectolite, shown in figure 116, because hyalite is an amorphous mineral, as it has no internal crystal structure and consequently shows no such radiated structure as pectolite when broken.

Geodes are concretions, very much larger than the "peas" of pisolite, and hollow, their interior often being lined with crystals. Figure 130 shows half of a geode lined with quartz crystals. In Iowa and Illinois

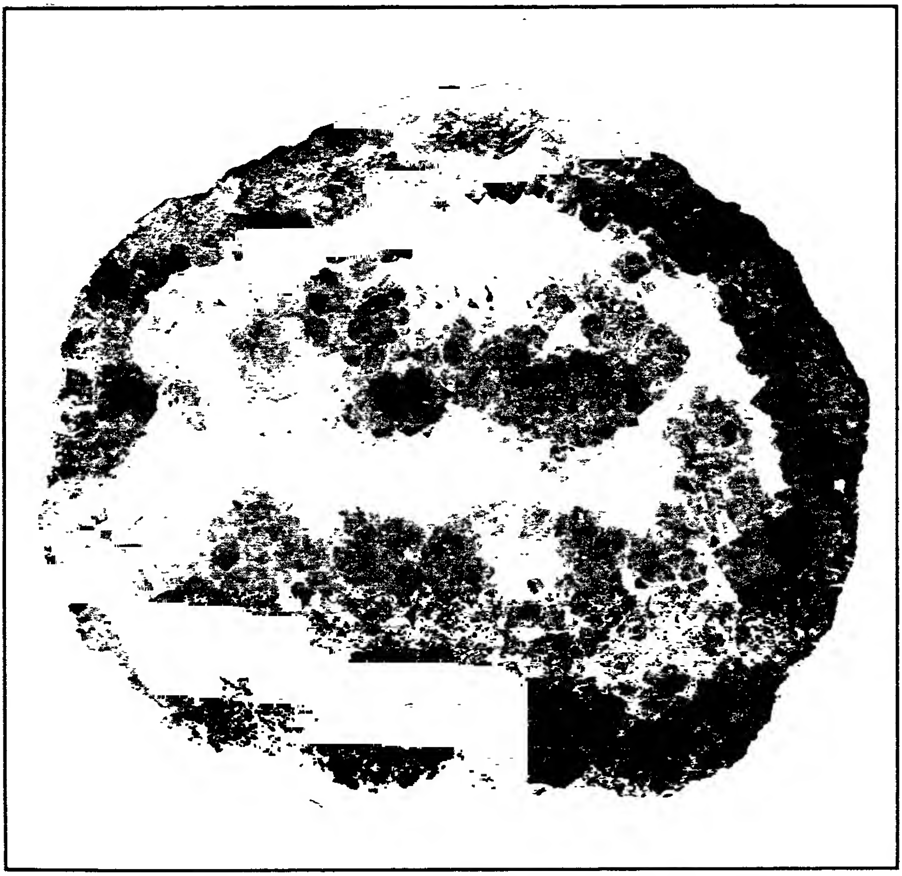


Figure 130. Geode, Lined with Quartz Crystals, Keokuk, Iowa

and many other localities such geodes are plentiful and average from two to six inches in diameter, but occasionally they are much larger or smaller. These mammoth "eggs" are to the mineralogist what dinosaur eggs are to the zoologist and paleontologist. In Uruguay, and elsewhere, geodes are found lined with rich purple crystals of amethyst quartz, sometimes surrounded with banded agate, figure 131, making exceedingly handsome specimens.

Another most interesting type of geode found in Uruguay is called *hydrolite,* or water stone. These hydrolites are chalcedony geodes partly filled with water carrying silica in solution. As the water evaporates the silica is deposited on the walls of the geodes as quartz crystals. Such specimens are highly instructive, as they show how crystals lining a great many cavities in rocks have been formed by the deposit of minerals held in solution.

Figure 131. Geode, Lined with Amethyst Crystals and Agate, Brazil. Courtesy of J. G. Manchester

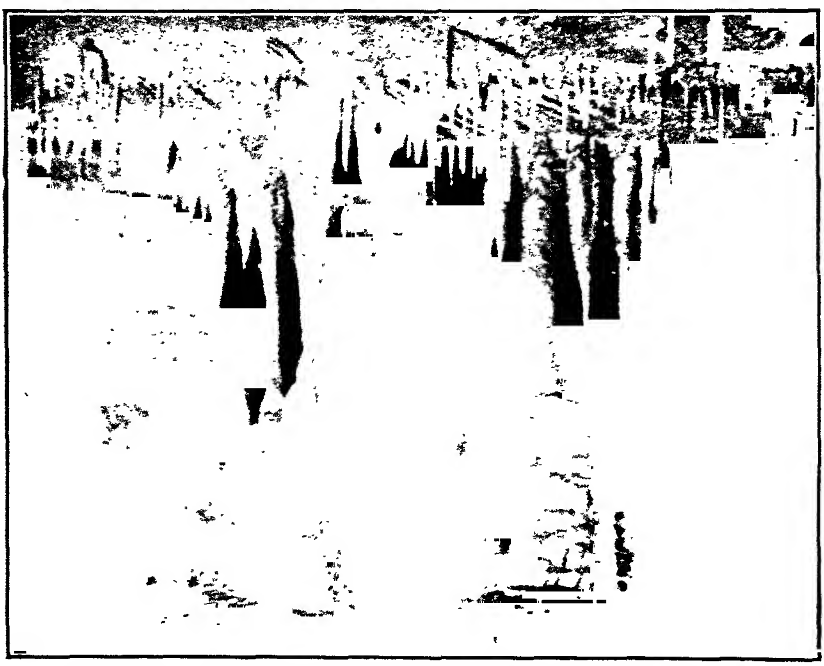


Figure 132 Calcite Stalactites and Stalagmites, Marengo Cave, Indiana

Caves are found in numerous sections of the world, especially in regions in which limestone abounds. Water percolating through this rock dissolves part of it and then, as it drips slowly from the roof of the cave, the limestone is redeposited in forms which mimic icicles and which are called *stalactites,* figure 132. Be sure to visit every cave you can, for scarcely two of them are alike and nearly all of them are beautiful. Internally, too, stalactites differ materially, some of them being coarsely crystalline while others are concentrically banded, as shown in figure 133. Many other minerals are found in stalactites, or groups of stalactites, among them are limonite and marcasite.

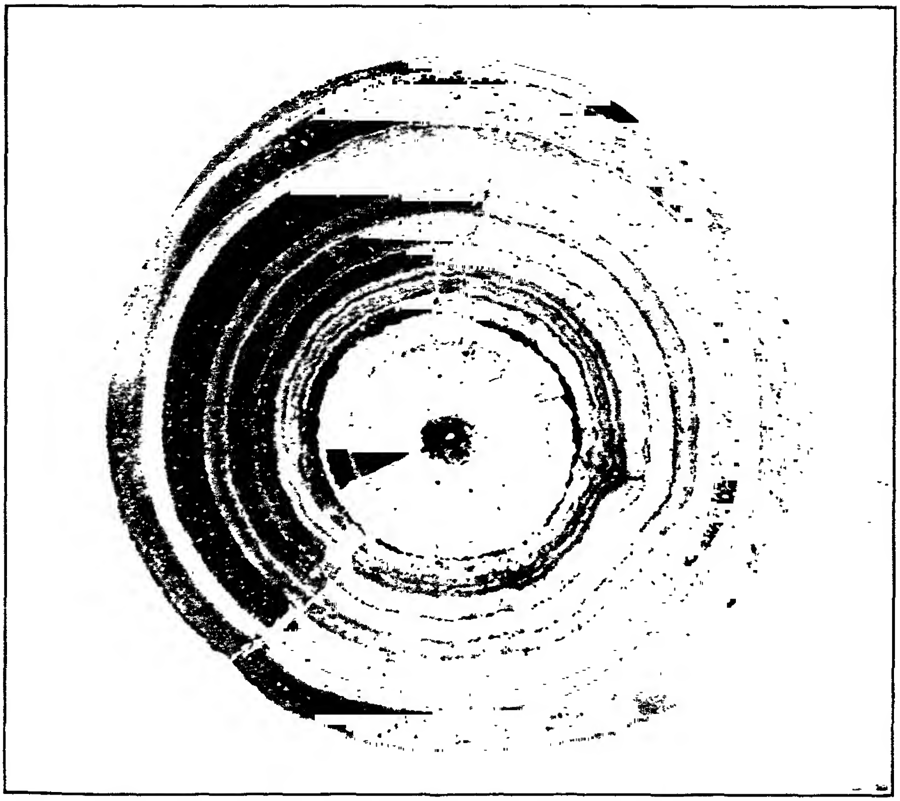


Figure 133. Cross Section of Stalactite, Showing Concentrically-Banded Structure

Stalagmites are the forms which are built up from the floor of the caves by the dripping water carrying mineral matter. They usually have much blunter points than the stalactites.

There is another type of mineral mimic which reminds us of the wolf in sheep's clothing. Mineralogists dignify it by the name *pseudomorph,* from the Greek words *pseudes, false* and *morphe, form.* It seems too

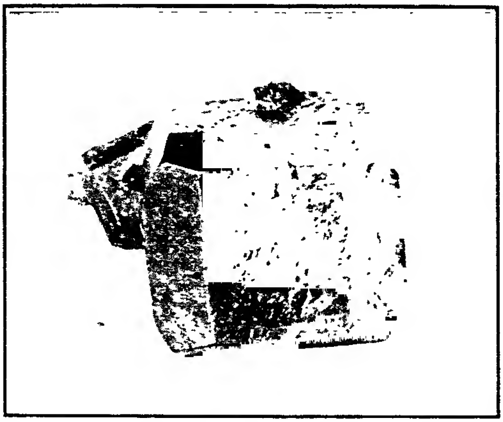


Figure 134. Limonite Pseudomorph after Pyrite, Waukarnega, South Australia

bad that the beautiful mineral kingdom should be degraded by the masquerading of one mineral in the form of another, but that is what a pseudomorph really is. You will have to watch out that you are not deceived by these pseudomorphs. One of them is very common in many localities; it is known as *limonite pseudomorph after pyrite.* When you

Figure 135. Petrified Tree-Trunk Forming Natural Bridge, near Holbrook, Arizona. Courtesy of Atchison, Topeka and Santa Fe Railway

Figure 136. Section of Opalized Limb, Clover Creek, Idaho. (Dr. A. E. Foote)

see forms, figure 134, exactly like the choice crystals of pyrite in the museums, except that they are brown in color, you can be quite sure that they are these limonite pseudomorphs after pyrite. There are some localities where they can be picked up in large numbers, while in Utah and the Island of Elba fine large specimens occur.

One of the most marvelous of the mineral mimics is "petrified wood."

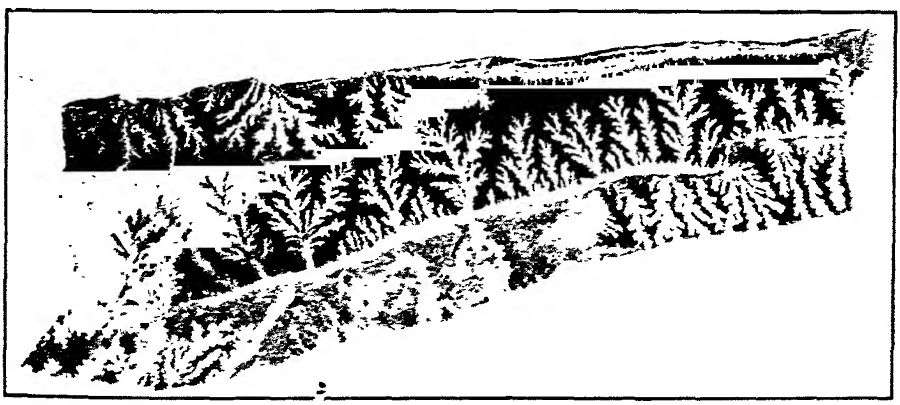


Figure 137. "Dendrites"; Tree-like Deposits of Manganese Oxide on Limestone, Solenhofen, Bavaria

In the "petrified forests" of Arizona, now a national reservation, there are trees three or four feet in diameter and over one hundred feet long, completely changed to quartz, or petrified. Petrified trunks and frag-

Figure 138. "Tree-Agate," India

ments of limbs and twigs are scattered over many square miles. In many places large trees may be seen, broken up into sections almost as though they had been sawn by a lumberman. At one place a petrified tree trunk spans a ravine about fifty feet wide forming a natural bridge,

Figure 139. Net-like Magnetite in Mica, Chandler's Hollow, Delaware

as shown in figure 135. The trees seem to have originally flourished on the shores of an inland lake, into which they fell and became water-logged. Then they were buried beneath volcanic material of a highly siliceous character which underwent alteration through the action of water, more silica being set free than the water could hold in solution. As the wood decayed, this silica (quartz) was deposited in its cells, until finally the woody fiber completely disappeared and what was once wood became stone. Because the change took place particle by particle, the minutest cells of the wood are preserved and may be seen under the microscope. Such silicified wood is by far the commonest pseudomorph, being found in large quantities in many localities.

Figure 136 shows a section of a silicified tree found in Oregon, in which the structure of the wood is remarkably well preserved. Here the mineral is opal instead of quartz. Such opalized wood, or wood-opal, abounds in northwestern Nevada and elsewhere.

Such huge trees as those of the petrified forest are not nearly as attractive as the charming little "trees" deposited on limestone at Solenhofen, Bavaria, and in other localities, known as *dendrites*, from the Greek *dendron*, a *tree*. Figure 137 shows one of these. Of great beauty also are similar formations in chalcedony, popularly known as "tree-agates," figure 138, or less correctly, *moss-agate*. The mineralogist appropriately names such forms *arborescent*, the Latin *arbor* meaning a *tree*. These differ from the arborescent forms mentioned on page 70 in that they are not groups of crystals.

The beautiful chalcotrichite, mentioned on page 59, mimics hairs. This is a common mimic in a number of other minerals.

Figure 139 shows a curious mimic of a net, sometimes seen in sheets of mica. It is really a crystallization of magnetite, similar in some respects to the reticulated cerussite shown in figure 97.

If you keep your eyes open, you will see many other mimics and if you use your imagination freely as you journey through life, you will see in minerals pictures, beautiful and interesting, which others will pass by.

Chapter 16

MARVELOUS CONTACTS OF LIGHT WITH MINERALS

It was early one summer morning when a party of enthusiastic mineral collectors, camping in the high sierras of California, reached the summit of a mountain to see the sunrise. A light shower was falling. Suddenly a shout went up as the sun slowly rose above the horizon in but slightly veiled splendor. Then another shout, and finally a chorus of exultant exclamations as their attention was called to the glorious rainbow in the South West. Their leader was not slow to seize the opportunity to impress on them that they were witnessing one of the contacts of light with the common mineral water in the form of rain drops. "What a glorious mineral water is," he said, then he promised that their morning's conference would be on the marvelous contacts of light with minerals.

1. TRANSPARENCY

After returning to camp, they breakfasted and, the morning chores being completed, assembled around the table, upon which their leader had placed a number of mineral specimens. Among them were four specimens of quartz, but they did not look at all alike. The first was a choice crystal of colorless quartz, clear as glass. The rays of the sun passed through it without interruption, even fine print could be read through it more readily than we can read "halite" through the specimen shown in figure 140. They were told that a mineral through which an object can be distinctly seen, is called *transparent*, from the Latin

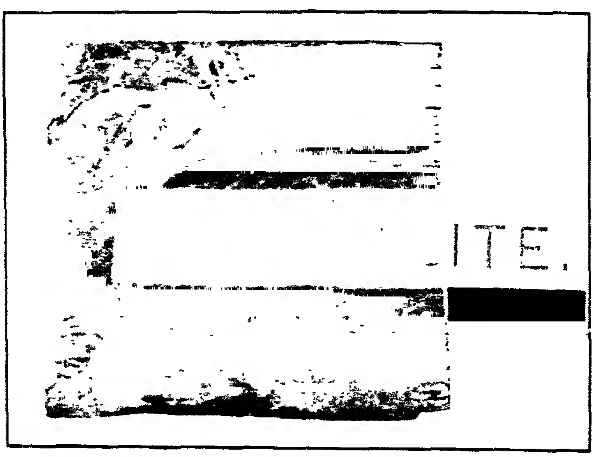


Figure 140. Transparent Halite, Stassfurt, Germany

words, *trans, through* and *parere, appear,* and that this is but another way of saying that light passes through the mineral uninterruptedly.

The second specimen of quartz, jasper, transmitted no light at all; it was *opaque,* so called from the Latin *opacus, darkened.* The other two varieties of quartz were chalcedony and flint, which they found were intermediate between these extremes. Chalcedony transmitted light throughout its mass, but not with sufficient ease to permit the outlines of a candle flame to be distinctly seen. Such a mineral, they were told, is termed *translucent,* from the Latin *trans, through,* and *lucere, shine.* Some rose quartz, they were told, is translucent, see figure 141,

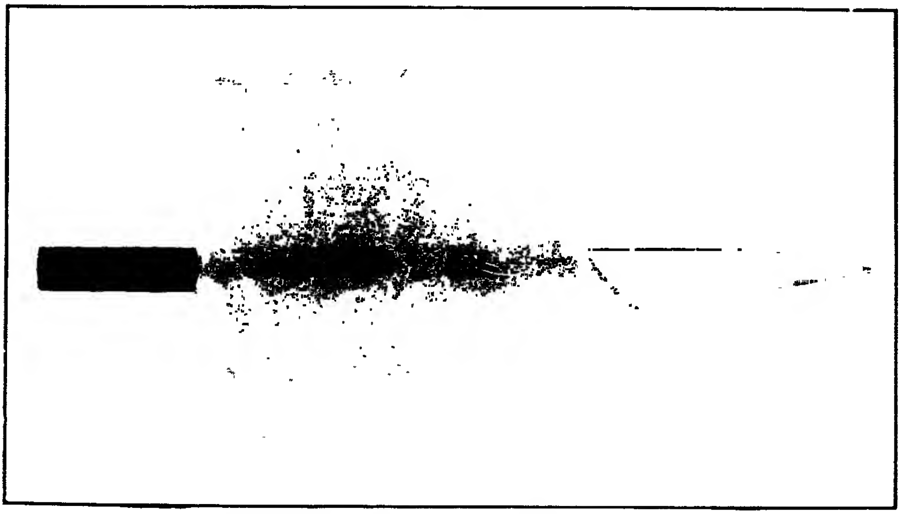


Figure 141. Translucent Rose Quartz, Stowe, Maine

while other material is nearly opaque. The flint transmitted much less light, indeed it was only when they held it up towards the sun that they could see a little light through the thinnest edges. Such a mineral is said to be *semi-translucent.*

Their leader explained further that the many varieties of quartz show great differences in the readiness with which they transmit light and he promised further study of this mineral after they returned home. He also told them that many minerals which are classed as opaque become transparent or translucent when very thin. Hematite, for example, though ordinarily perfectly opaque in large masses, transmits a deep red light in very minute and thin crystals or scales, or in very thin films between folds of mica. Even gold transmits a green light when in very thin leaves.

It was their last day in camp, but their delightful contacts with min-

erals in the field aroused their enthusiasm for continuing their study of minerals

2. COLOR

Two boys, Bob and Dick, were looking at the same crystal of tourmaline. Bob was standing with his back to the window, holding the crystal in front of him. Dick was facing him on the other side of the crystal. Bob said: "Isn't this a fine, black crystal!" Dick replied, "Black! I beg your pardon. It's green!" Both of these boys were right, yet each was sure the other was wrong. How could that be? An older collector came to their rescue and explained that some minerals show one color when looked *through*, by *transmitted* light and another color when looked *at*, by *reflected* light. He invited them to see his collection and there they saw tourmaline crystals from Pierrepont, New York, which were black by reflected light, and, being opaque, they did not transmit any light; while his tourmaline from Macomb, New York, not far away, was black by reflected light, but brown by transmitted light. He also showed them tourmalines from Brazil which were almost black by reflected light, but a beautiful rose-pink by transmitted light. One of his Maine tourmalines was black by reflected light and deep blue by transmitted light, while some crystals from South West Africa which were black by reflected light, were green by transmitted light. What a wonderful variety of colors this mineral exhibits!

Some minerals not only transmit a different color from that which they reflect, but also transmit two different colors when the light passes through them in different directions. Because the Greek word *dichroes* means *two-colored*, this property of transmitting two colors is called *dichroism*. If the boys had revolved the crystal they were examining they would very likely have found that it showed this property of dichroism, but they overlooked it, as so many others do, because they did not realize how much there is to be seen in minerals.

The bright surface colors of many minerals are one of their most captivating features. Everyone thrills at the sight of the lovely rainbow, so why not have a "rainbow collection of minerals," embracing minerals carefully selected to show the rainbow colors? Some of the colors are easily secured, others are scarce, but the forming of such a collection will be an inspiring road to a knowledge of the very fascinating subject of color.

Great differences of color are to be found even in a single mineral, as we have just seen in the tourmaline. Azurite may be so dark a blue that it is practically black, or it may pass by many gradations into a charming sky-blue or "azure blue." Corundum shows a truly marvelous variation in color, the variety ruby being deep, rich ruby-red; sapphire

is pink, purple, blue, yellow, green to white, while the coarser kinds of corundum are usually gray or brown and the variety *emery* is black.

The collector who is alert for specimens of attractive colors, will surely have a spectacular collection and, incidentally, he will find new pleasure in observing the colors in paintings and fabrics, in butterflies and flowers, indeed wherever he goes color will assume a new and delightfully inspiring influence in his life.

Many minerals have such characteristic colors that they are well-known to buyers of ribbons, silks, and other fabrics; thus there are emerald-green, malachite-green, sulphur-yellow, ocher-yellow, amber-yellow, sapphire-blue, and so on. The mineral collector will soon find that very few minerals are always, or even usually, of uniform colors, though at times, color is a valuable aid in identification.

Care must be exercised not to be led astray by placing too much reliance in it. Biotite mica is generally black, phlogopite mica is usually dark brown, and muscovite mica white, light brown, or green; but it is not safe to depend on these colors as an invariably safe means of determining these minerals. There is a pale green biotite at Vesuvius and a white phlogopite in northern New York. While in probably nine cases out of ten the color of the mica will enable us to identify it, the tenth case will come sometime, so it is always better to let our determinations rest on more than one of the physical properties.

The color of a metallic mineral is far more uniform than that of a non-metallic mineral; therefore, color is a far safer guide in determining metallic than non-metallic minerals. Owing to the constancy of color of the metals, there is a wide use of such terms as golden-yellow, copper-red, lead-gray, silver-white. We must observe, however, that while there is great uniformity in the fundamental color of these and other metals, there are many shades due to impurities, especially in gold; thus the gold from Verespatak, Transylvania, which frequently contains thirty per cent or more of silver, is much lighter than pure gold.

Among non-metallic minerals the terms used to describe their colors are largely based on the well-known colors, with substances whose colors are familiar to everyone used as prefixes; thus a pure white marble is called "snow-white," the common English flint is "smoke-gray," black tourmaline from Pierrepont and elsewhere is "velvet black," amethyst is "violet-blue." A mineralogist would never use such a term as "garnet-red" because he knows that few minerals vary in color as much as garnet, even though some shade of red may be more common than any other color.

It may seem so surprising as to be almost incredible to learn that the external colors, as well as those shown by transparent minerals by trans-

mitted light, are not really their true colors after all. What then, are their essential colors?

3. STREAK

The external, or superficial, colors of minerals, which first appeal to the eye, are not nearly as important a guide in the determination of minerals as the color of the mineral when powdered, which is known as its *essential color, or streak.* This streak is often very different from the surface color. While different specimens of a mineral often show different superficial colors, its streak varies but little.

There are several common methods of testing the streak of a mineral; first by crushing it to a powder with a hammer, second by scratching it with a knife blade or a file, third by rubbing it on what is known as a streak plate. This is usually a piece of unglazed porcelain, with a rather rough surface. Streak plates may be purchased at small cost, or the little six-sided tiles used for flooring will answer well. Rubbing on a streak plate is the most satisfactory method of testing the streak of the softer minerals, for in this way the color is preserved on the streak plate and can be compared conveniently with that of other minerals whose streaks can be made close to each other.

Minerals whose hardness exceeds that of the streak plate, however, cannot be tested on it, for instead of leaving their own powder on the plate, they will scratch it and produce the streak of the plate rather than their own. The simplest ways of testing the streak of hard minerals are with a file or by powdering them with a hammer.

Some interesting surprises await us when we test streak. Here are some of the results we may expect to secure:

Mineral	External Color	Streak
Apatite	Blue-green	White
Calcite, blue	Sky-blue	White
Chalcopyrite	Brass-yellow	Greenish-black
Cinnabar	Grayish-red	Scarlet
Cuprite	Cochineal-red	Brownish-red
Fluorite	Green, purple, or blue	White
Galena	Lead-gray	Lead-gray
Hematite, micaceous	Iron-black	Brownish-red
Hematite, compact	Steel-gray	Brownish-red
Limonite	Dark brown	Ocher-yellow to rust brown
Malachite	Bright green	Pale green
Manganite	Iron-black	Reddish-brown
Pyrargyrite	Black	Purplish-red
Siderite	Brown	White
Talc	Gray or green	White
Zincite	Deep red	Orange-yellow

It is especially interesting to note that all of the above minerals which have a metallic appearance, with the single exception of galena, have

a streak very different from the external color and that most of the others have a streak which is white, or nearly white. It is quite surprising to see that fluorite, whose external color varies greatly, some specimens being green, others purple or blue, always gives a white streak. It is the same with calcite which gives a white streak even though its external color is blue, salmon, yellow, or gray.

4. LUSTER

If we compare galena with transparent quartz we shall see that, irrespective of color, it reflects light differently. Probably this property is best described as its *shine,* but mineralogists call it *luster.*

It is very important to understand this property, for most works on determinative mineralogy make the decision as to whether a mineral has a metallic luster the first step towards its identification.

Let us begin our study by carefully examining the surface appearance of all of the metals we can find—gold, silver, copper, aluminum. tin, lead—there are many others. We note that there is a peculiar, brilliant shine to every one of them, and though some may be superficially tarnished, a fresh surface always shows the typical *metallic luster.* We find also that there are many other minerals with this same metallic appearance, most of them being compounds of sulphur or, more rarely, arsenic or antimony, with metals, or else they are oxides of the metals. If you look through a museum whose minerals are arranged according to Dana's "System of Mineralogy," you will find that there are no minerals with metallic luster after passing the oxides, with the single exception of the very rare species långbanite. If you remember this fact you will be sure, when you see a mineral with metallic luster, that it is not a carbonate, silicate, phosphate or sulphate. Remember too that all minerals with metallic luster are opaque.

The faces of a clear quartz crystal reflect light very differently from the metals, though their luster is often equally brilliant. It may be impossible to describe the difference, but the eye instantly recognizes it and we feel sure that minerals of this character have a *non-metallic luster.* Actual specimens are more essential in the study of luster than in any other property of minerals.

The terms used to describe the various kinds of non-metallic luster are all derived from the luster exhibited by well-known objects, such as glass, resin, wax, grease, pearls, satin, silk.

Adamantine luster is that peculiar, bright, somewhat oily flash so characteristic of diamond. It is natural to associate it with hard minerals and it is possessed to a marked degree by the two hardest of all minerals, diamond and corundum, which is sometimes called "adaman-

tine spar." Cassiterite and zircon, also hard minerals, show adamantine luster, but it is not confined to hard minerals for cerussite and anglesite, two quite soft lead minerals have adamantine luster. All six of the minerals named have a high index of refraction (page 110) and it has been suggested that there is some connection between these two properties.

Vitreous luster is that surface reflection shown ideally by broken glass. The name is derived from the Latin word for glass, *vitrum*. A transparent quartz crystal is one of the best illustrations, but some of the massive varieties of quartz, like flint and jasper, are not vitreous. It is probably the commonest of all kinds of non-metallic lusters.

Resinous, or *waxy luster* is that kind of surface reflection exhibited by the fossil resins, copalite and amber. It is also often well shown by sphalerite and by sulphur. It grades off into *greasy luster*, which is well shown by some varieties of serpentine, some massive quartz, and especially well by elaeolite.

Pearly luster derives its name from the beautiful sheen (not the play of colors) of mother of pearl. This luster is especially common among minerals which have a foliated structure and those which have an excellent basal cleavage such as the micas, also heulandite, apophyllite and foliated talc. Bronzite has a *metallic-pearly luster*.

One of the most beautiful lusters is *satiny*, or *silky*. Its best illustration is satin spar, a fibrous variety of gypsum, which is extensively cut into cheap jewelry and sold at Niagara Falls and other tourist resorts. Satiny luster is characteristic of fibrous minerals and is beautifully shown by the fibrous serpentine, chrysotile or "asbestos," and also by the South African crocidolite, "blue asbestos," and by its alteration into quartz, called "tiger-eye."

When a mineral shows no luster it is said to be *dull*; if soft and easily crushed it is *earthy*.

Examine all of your specimens and those you see elsewhere and record what you think is the luster of each one; then check up your determinations with a reliable textbook.

DIFFERENCES BETWEEN TRANSPARENCY, COLOR AND LUSTER

We have been studying about three of the contacts of light with minerals. Before passing on to other even more wonderful contacts, let us get clearly in our minds the differences between these three properties.

Transparency is the *quantity* of light *transmitted.*
Color is the *kind* of light *transmitted or reflected.*
Luster is the *manner* in which light is *reflected.*

5. REFRACTION OF LIGHT

Refraction. Two sportsmen were fishing from a boat in perfectly clear water. Suddenly a water snake swam leisurely across their bow. The one who saw it first fired at it with his revolver, aiming directly at its head. He was a good shot and was amazed that he missed it. As it came to the other side of the boat, the second sportsman fired at it, aiming a considerable distance below its head and he hit it. Why? It was because he had remembered a well-known fact that when a beam of light passes into a denser medium, as from air into water, it is bent, its direction becoming more nearly perpendicular. This phenomenon is called *refraction*. Look at figure 142. Suppose a ray of light originating at D strikes the surface of the water at A, passes through it and

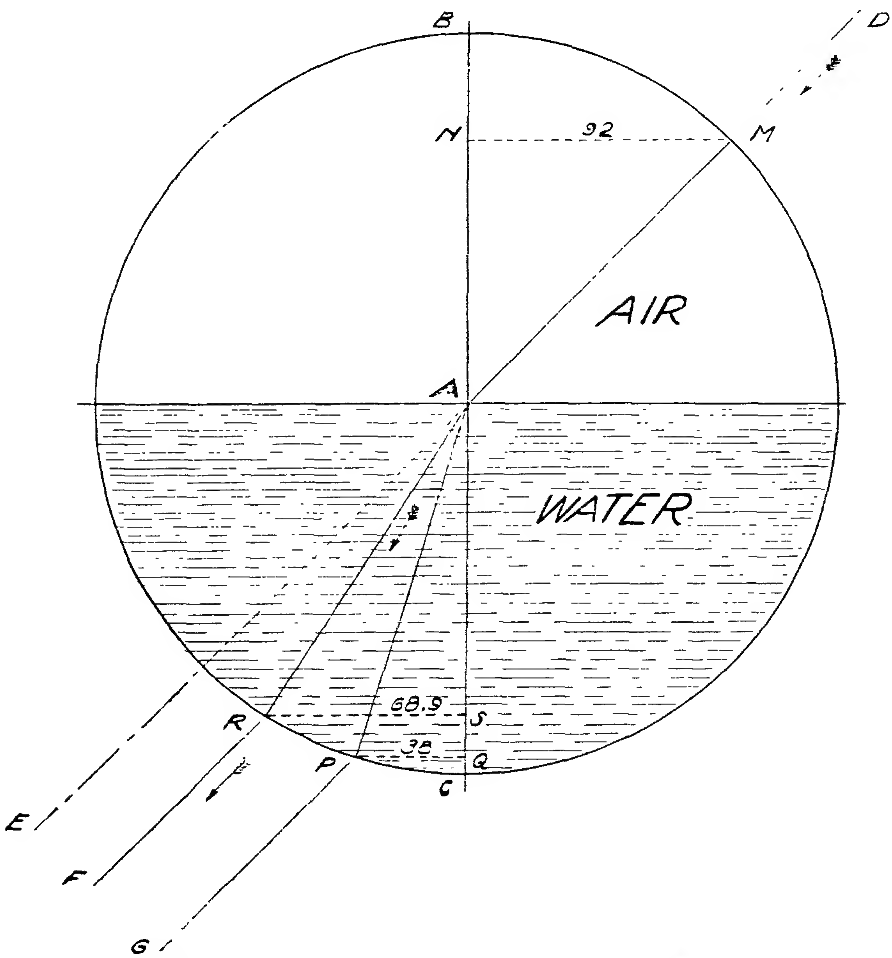


Figure 142 Refraction of Light by Water and Diamond

emerges at R. When it strikes the water it is bent, or refracted, towards the perpendicular line BAC; when it emerges into the air it is again bent, this time away from the perpendicular, and resumes its original direction.

Index of refraction. Rays of light entering a given mineral, say diamond, are always bent to exactly the same extent every time, but one mineral differs from another in the extent to which it bends the rays. These facts often enable the mineralogist to positively determine the identity of an unknown mineral by ascertaining the exact extent of this bending, which is called its *index of refraction*. Such exact determinations involve the use of expensive instruments, which usually are beyond the reach of the beginner, but it is easy to understand the general principles of refraction of light by referring again to figure 142. Assuming that the distance from N to M is 92, the distance from S to R would be 68.9, and dividing 92 by 68.9 gives us 1.335 which is the index of refraction of water. If diamond were substituted for water, the ray entering at A would be bent much more towards the perpendicular BAC, that is in the direction AP, and it would be found that the line PQ would measure 38. Dividing 92 by 38 would give 2.42 as the index of refraction of diamond. The index of refraction of most minerals is in the neighborhood of 1.55 and very few exceed diamond.

Dispersion of light. Another interesting fact in reference to refraction of light is that rays of light of different colors are bent differently. Red rays are bent less than blue. When, therefore, a beam of white light passes into diamond it is split up into the rainbow or prismatic colors of which it is composed. Because diamond has high dispersive power the colors are separated widely and we see a broader band of rainbow colors than in any other of the well-known gems.

Double refraction. It has been found that all transparent minerals except those which crystallize in the isometric system or those which are amorphous, break up a ray of light passing through them into two rays, so that an object seen through them appears double. In most minerals, however, the divergence of these two rays is so slight as not to be perceptible to the unaided eye. In transparent calcite, often called "Iceland spar," the rays are so widely separated as to make this property, known as *double refraction*, very striking, as shown in figure 143. Do not fail to get a specimen of Iceland spar and prove for yourself that you can see two images of any object through it where only one object exists. One of the notable specimens in the British Museum in London is a huge crystal of transparent calcite, Iceland spar, about 27 by 24 by

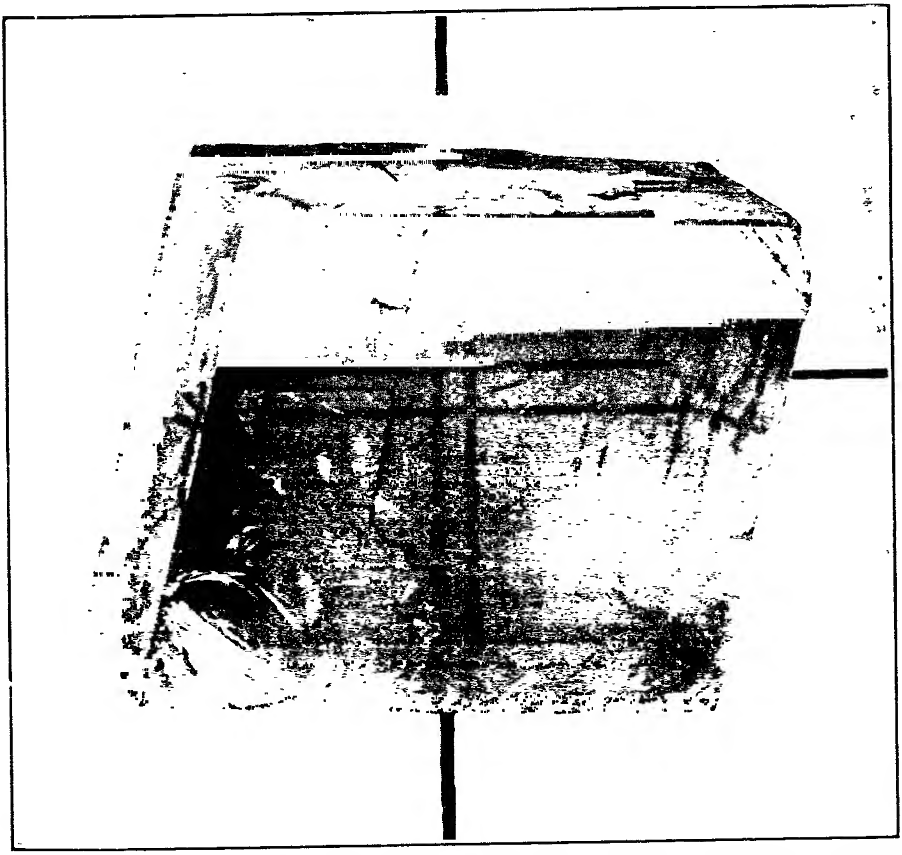


Figure 143. Double Refraction of Light by Iceland Spar. Museum of Brooklyn Institute

18 inches. A cross has been placed behind the crystal and a surface has been cleaved in front, enabling the visitor to look through twenty-four inches of the mineral. What does he see? Not a single cross, but two crosses, apparently about three inches apart!

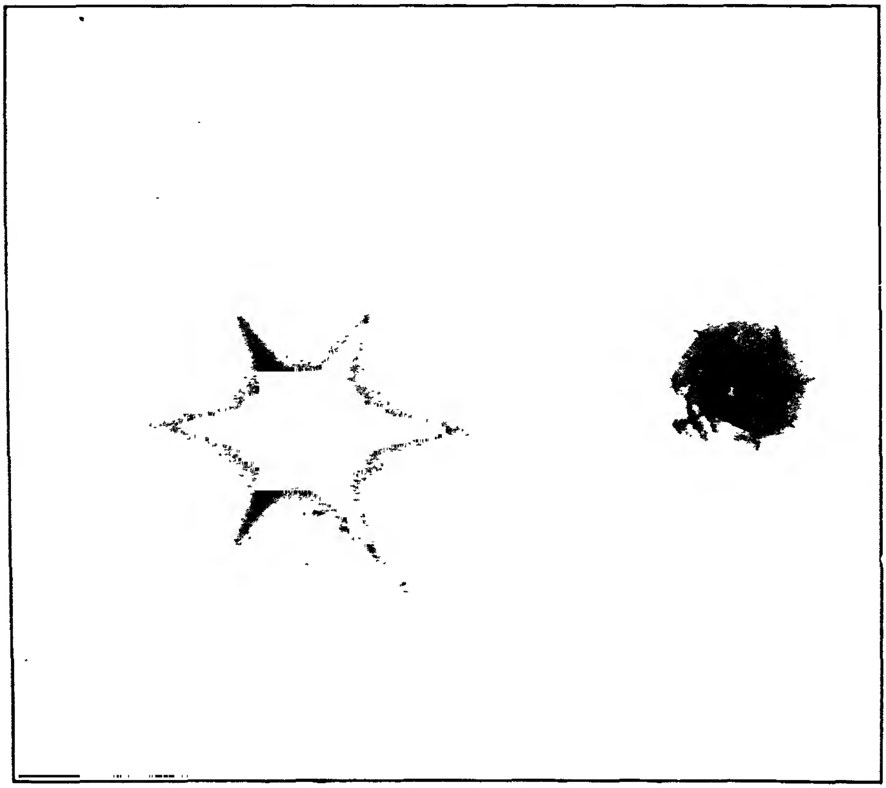
This subject of the refraction of light becomes more and more fascinating as it is studied more deeply and it leads on to a later study of *polarization of light* with the glorious displays of color visible in thin sections of rocks when viewed under the petrographic microscope. Nothing more beautiful exists in nature.

6. ASTERISM

Another curious contact of light with minerals owes its name to a Greek word, *asterismos*, from *aster*, a *star*. An inexpensive specimen which will afford much pleasure to any collector is a thin sheet of phlogopite from South Burgess, Ontario, which shows *asterism*. Hold

a sheet of this mica close to the eye and look at a light through it and you will see a bright six-rayed star, like figure 144, or possibly two or even three stars, though the extra ones will be less distinct. These stars are due to the reflection of light from very minute crystals of rutile (or possibly tourmaline), symmetrically arranged between the layers of mica.

Another less common, but much more highly prized, instance of asterism is the star-sapphire. This is pictured in figure 145. Unlike phlogopite, the star sapphire shows its beauty only by reflected light. The asterism is due to structural conditions rather than inclusions.



Figures 144, 145, Asterism of Phlogopite and Star Sapphire

Chapter 17

"BLACK LIGHT" AND OTHER COLOR PHENOMENA

1. FLUORESCENCE

Fluorescence is one of the most remarkable phenomena in the mineral kingdom. It has recently been winning thousands to the love of minerals, because of the introduction of an inexpensive argon-filled bulb, figure 146, which can be screwed into any standard electric light socket. Many minerals show fluorescence under this bulb. What is this strange property?

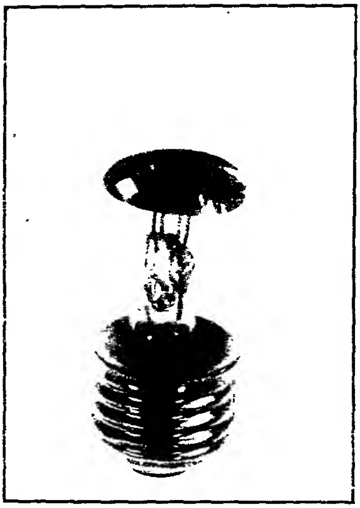


Figure 146. Argon-Filled Bulb for Showing Fluorescence

While minerals exhibit it probably more beautifully than any other objects, an understanding of it requires a journey into the realm of optics.

When a beam of sunlight passes through a triangular prism of glass, its white light is split up into rays of light of all the colors of the rainbow. This band of colors is known as the solar spectrum. Beyond these visible rays, at both ends of the spectrum, there are other rays of light, not visible to the human eye, far outnumbering the visible rays. These are grouped respectively under two headings, the ultra-violet rays and the infra-red rays. It is the ultra-violet rays, popularly called "black light," which produce fluorescence in minerals and other substances.

When invisible ultra-violet rays fall on certain minerals, the length of the waves of light is changed to that of visible rays and these are emitted as colored rays of cold light, as long as the mineral is exposed to the ultra-violet rays. *Fluorescence,* then, *is the emission of colored light rays by a substance during exposure to ultra-violet rays.*

Many colors, ranging through the entire spectrum, are produced, but these colors vary with the sources of the ultra-violet rays and the character of the material exposed to them. Let us see what results we can secure with an argon bulb in a perfectly dark room. We screw the little 2-watt bulb into a 110 volt A. C. circuit and turn the button. We see a violet glow, but this is not what produces fluorescence; it is the invisible rays. Hold close to the light a piece of fluorite from Weardale, England, which by natural light is green or purple. See! it glows with an indescribably beautiful blue light! Next we expose a brown fluorite from Clay Center, Ohio; it becomes a yellowish-green. Willemite from Franklin, N. J. of pale green or yellow color, glows with a bright green light. Gray sphalerite from Tsumeb, South West Africa becomes bright, golden yellow. Cream-yellow semi-opal from Virgin Valley, Nevada, becomes a charming yellowish-green. Other minerals respond to the ultra-violet rays differently. You will find great pleasure in testing all of the minerals in your collection. Some of them will show fluorescence: many of them will not.

It is a safe prediction to make that what you see of fluorescence under an argon bulb will cause you to visit a museum in which one of the more expensive lamps is installed. There are several well-known types, such as the carbon arc, the iron spark-gap and the mercury-vapor arc. By actual tests it has been found that the new "Nico" lamp, figure 147, is the most efficient This is a mercury-vapor lamp with the ultra-violet

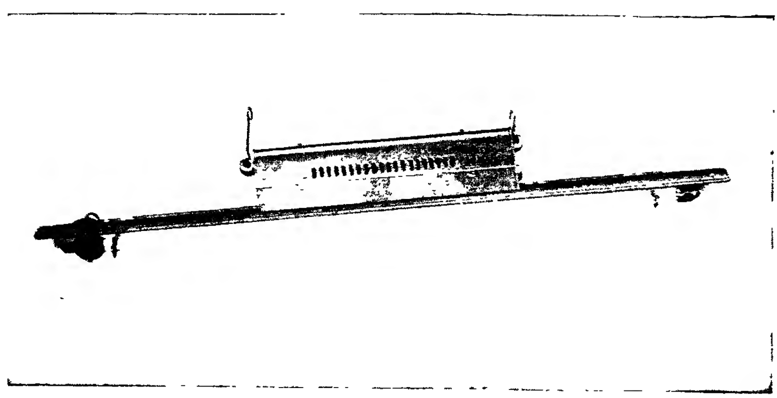


Figure 147. "Nico" Mercury-Vapor Lamp for Showing Fluorescence

rays given off from a long tube of nickel-cobalt glass. The fluorescence produced by the aid of this lamp has been well called "the acme of beauty."

It may occur to you to wonder whether fluorescence has any practical applications in every-day life. Like most discoveries in science, its usefulness was not appreciated for a long time, but now it is becoming one of the best servants in many activities. Just to mention a few: By its aid counterfeits are detected; changes on checks and legal documents are revealed; finger-prints which are invisible by daylight may be seen; wool can be distinguished from cotton and mineral oils from vegetable oils; the presence of even one one-hundredth of one per cent of contamination in medicinal oil is clearly revealed; cider vinegar is distinguished from acetic acid; many adulterations of foods and drugs can be detected; beautiful or startling effects are produced on the theatrical stage.

2. PHOSPHORESCENCE

Phosphorescence differs from fluorescence in that the emission of light continues after the exciting rays have been shut off. For this reason if phosphorescent bodies are exposed to sunlight, which is rich in ultra-violet rays, and then quickly removed to a dark room, they continue to glow. Many minerals and other substances phosphoresce for a long time, but as a rule the light quickly fades from sight, though it may be detected by a photographic plate long afterwards. Willemite, of certain kinds, is brilliantly phosphorescent after exposure to ultra-violet rays; so are certain kinds of calcite and sphalerite. A great many minerals are phosphorescent, but the property is not noticed because the phosphorescence does not last until the eyes become adjusted to the darkness which is essential in order to see it. If the eyes are closed while the current is turned on and opened simultaneously with its turning off, phosphorescence will be seen much more frequently.

3. IRIDESCENCE

Did you ever hear of "rainbows in stones"? Look over your transparent specimens and see if you can find one. They are often beautifully shown on the flaws inside of clear quartz and calcite. Mineralogists call such rainbows *iridescence*, from the Latin *iridis*, the *rainbow*. Iridescence is not, however, always inside the mineral, but may appear on its surface, as sometimes on anthracite, hematite, pyrite, chalcopyrite, bornite. It is due to the breaking up of the white light falling on the specimens into the rainbow colors of which it is composed.

4. TARNISH

Tarnish differs from iridescence only in the fact that it is produced by the permanent alteration of the surface to a different single color. Silver, for example, is often tarnished black, and the copper-red of copper is changed to black. If, however, several colors are produced on the surface by the process of tarnishing, the result is called iridescence and not tarnish. If you break a piece of bornite, you will be surprised to see that the blue and green surface iridescence, produced by tarnishing, is very different from the peculiar reddish-brown color of a fresh surface. As many minerals show such superficial alteration, it is important, when describing the colors of minerals always to examine a fresh surface.

5. PLAY OF COLORS

Some minerals, notably precious opal, show a *play of colors* inside when the mineral is turned. This is usually due to reflection of light from very minute cracks. In the case of diamond and some other cut gems, which are noted for their gleaming play of colors, the effect is produced by the splitting up of the light and the reflection of the separate colors from the inside surfaces of the facets of the gem.

6. CHANGE OF COLORS

Change of colors, also called *chatoyancy,* from the French, *chatoyer, to change color,* is a remarkable property of a few semi-precious stones such as labradorite, tiger-eye, and cat's-eye. Take a piece of labradorite from Labrador and turn it until at a certain angle you see most vivid colors flash forth in great sheets. Turn it still further and they disappear and the lifeless gray of the mineral takes possession of the surfaces which a moment before showed such a gorgeous blue, yellow, or red change of colors. The cat's-eye effect is often produced by fibers of asbestus or is caused by cavities arranged in parallel position. These reflect the light more brightly as it falls on the crystals within.

7. SCHILLER

Continue revolving the labradorite until you reach a place at which you see beautiful iridescent reflections from the surfaces of exceedingly minute crystals enclosed in the mass. The crystals are so very small that you can scarcely see them, but with a good lens or under the microscope they are dazzlingly beautiful. Figure 148 shows a specimen of sunstone, a variety of feldspar, in which the little enclosed crystals have been magnified ten diameters. The dark parts are the crystals which produce the gorgeous schiller or *iridescent reflections.*

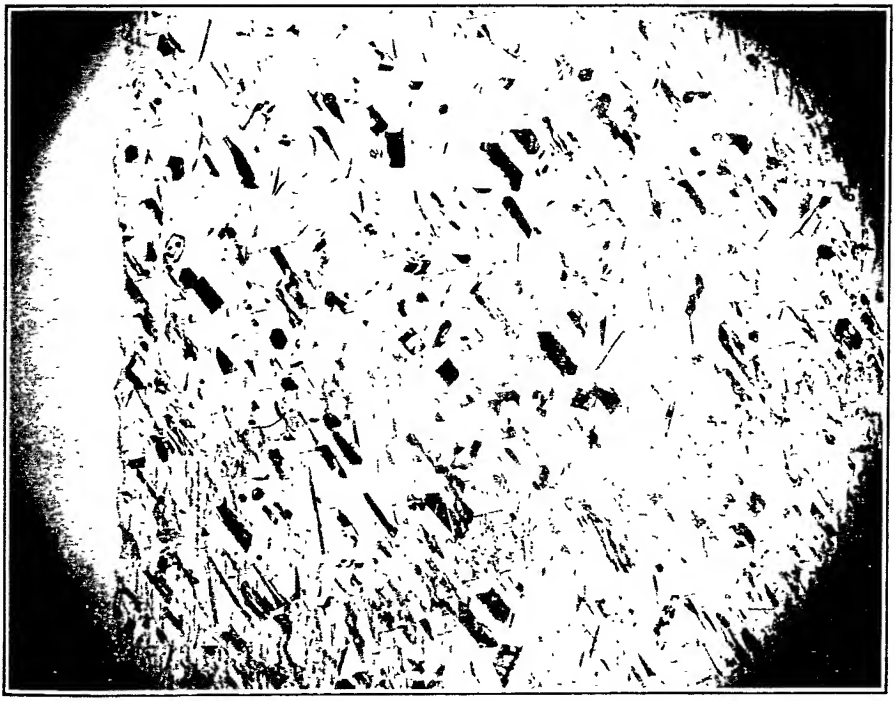


Figure 148. Sunstone, Norway, Magnified to Show Enclosed Crystals Which Produce Schiller

8. OPALESCENCE

Opalescence is a milky reflection from within a mineral. The name calls attention at once to the existence of this property in the opal, but it seems unfortunate that the name is used to describe a milkiness which detracts from the beauty of the noble opal gem instead of being used for the play of colors which makes the opal one of the most beautiful of all gems. Opalescence is also shown by a variety of feldspar called moonstone. Here again we must be careful not to confuse the milky or pearly reflection which constitutes its opalescence with the change of colors which is the far more prominent and beautiful feature of the moonstone. In this instance, however, the two properties are generally combined in a single specimen, while in fine gem opals the opalescence is generally lacking.

We have scarcely more than glanced at the marvelous contacts of light with minerals. A great literature has accumulated on this subject as the result of the patient investigations of many research workers. There is much more still to learn and many applications in every-day life will doubtless result from further work in this alluring field.

Chapter 18

ELECTRICAL AND MAGNETIC PHENOMENA

1. ELECTRICITY

Electrical phenomena among minerals are rarely visible to the beginner, though of great interest. Much progress has been made by advanced workers in chemistry, physics, and mineralogy in coming to an understanding of the manifestations of electrical energy. The most important of these are connected with the electrons and protons about which we studied in chapter 4, and the revelations as to the structure of the atoms and molecules, when crystals are examined with X-rays. The beginner may look forward with anticipation of keen pleasure to the day when he will be sufficiently trained in the physical sciences to tackle for himself the problems which are now arousing enthusiastic study in research laboratories.

The ability to conduct an electric current is possessed to a marked degree by the metals. It has enormously important applications in every-day life in such inventions as the telephone, telegraph, radio and trolley. Most of the non-metallic minerals are non-conductors of electricity. The use of mica as a non-conductor in telephones and other electrical instruments is well known.

You can easily perform a simple and striking experiment, to show the presence of electricity, by rubbing a piece of copalite with a silk handkerchief on a clear, dry day. In a few moments it becomes electrified and will pick up tiny bits of tissue paper, as shown in figure 149. All minerals become charged with electricity by friction of this kind, but few show it as distinctly as copalite and the closely related fossil resin, amber. It is an interesting fact that the word *electricity* is derived from the Greek name for amber, *elektron*.

2. MAGNETISM

The property of *magnetism* has been shrouded with mystery and superstition by the ignorant from ancient times. Even today many people carry with them a piece of lodestone as a "rheumatism cure"! The explanation of magnetism belongs in the realm of physics rather than mineralogy, but the manifestations of the force among minerals are worthy of attention.

The mineral magnetite is the only one which strikingly illustrates the property, though platinum and pyrrhotite are slightly magnetic and ilmenite, chromite, franklinite, hematite and limonite sometimes show

a little response to the magnet. It is possible that this is due, at least in some instances, to the presence of magnetite as an impurity. Pyrrhotite, however, is attracted by the magnet to such an extent that it has been given the popular name of "magnetic pyrites."

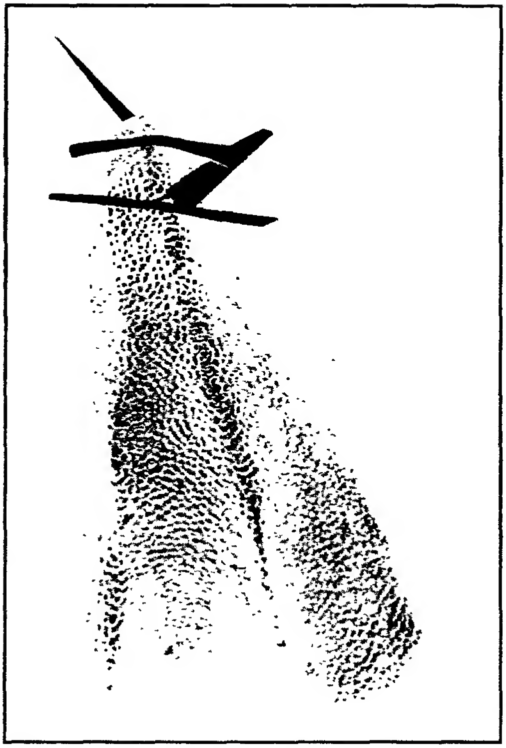


Figure 149. Demonstration of Frictional Electricity in Copalite, Zanzibar

Magnetite is invariably strongly attracted by a magnet, and if you are in doubt as to the identity of a black mineral and find that a small piece of it will jump to a magnet, you can be sure that it is magnetite.

An electro-magnet, which consists of an iron magnet through which a current of electricity is passing, will attract many minerals not visibly affected by the ordinary "horse-shoe" or the "bar" magnet, indeed all minerals are affected, though in greatly varying degrees, by the force when placed between the poles of an electro-magnet. This fact has been utilized commercially in the separation of the different ingredients of sands and concentrates at many mines. Iron compounds are most strongly affected.

The most interesting exhibition of magnetism among minerals is in the variety of magnetite known as *lodestone*. This remarkable mineral

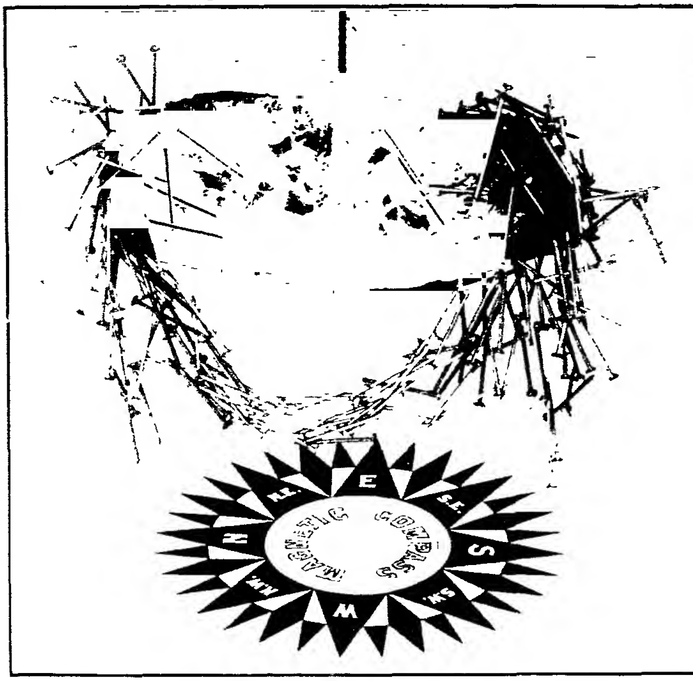


Figure 150. Demonstration of Polarity of Lodestone

will not only pick up small objects of iron or steel, but, when suspended by a string so that it can swing freely, will always come to rest in the same position, a certain place being towards the North and another towards the South, as shown in figure 150. Note also that the nails are picked up chiefly at these places, which correspond to the North and

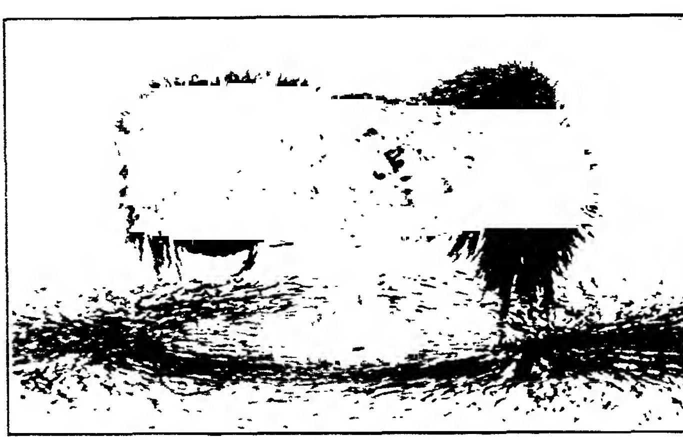


Figure 151. Weak Lodestone Picks up Iron Filings

South poles of a compass. The mineral is, therefore, said to have *polarity.* If we bring a compass near to the suspended lodestone, we will find that the North pole of its needle will be attracted by the South pole of the lodestone, and that the South pole of the needle will be drawn to the North pole of the lodestone.

Lodestone varies greatly in strength. Some of it will pick up fine iron filings, figure 151, while other pieces will not only pick up nails

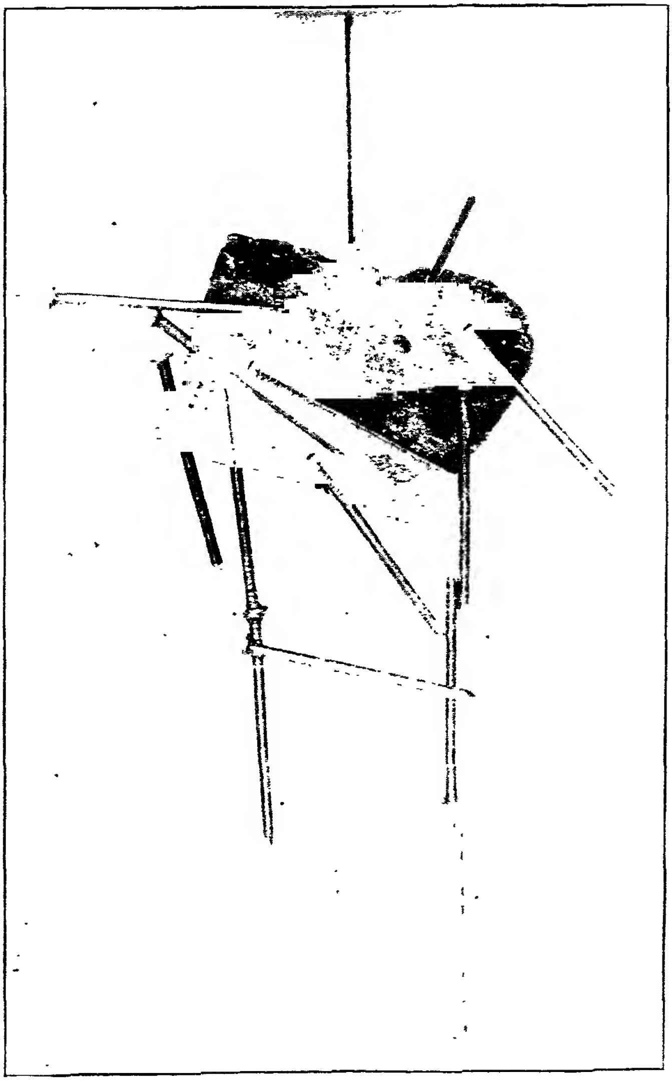


Figure 152. Strong Lodestone Picks up Ten-Penny Nails

as heavy as ten-penny, but others of these heavy nails can be suspended from the nearest nails, figure 152.

While ordinary magnetite is an exceedingly common and widely distributed mineral, the variety lodestone is found in comparatively few localities, and usually in small quantities. One of the most famous localities is Magnet Cove, Arkansas.

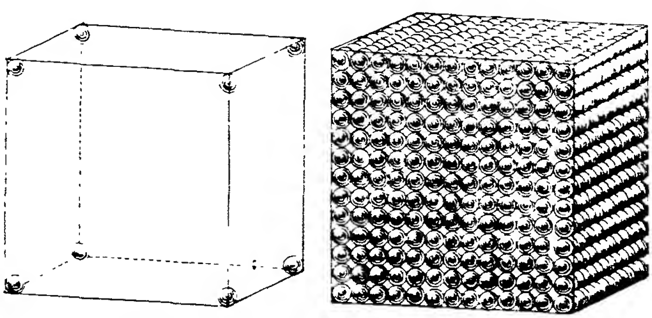
Chapter 19

WHY MINERALS VARY IN WEIGHT

If we pick up pieces of galena and quartz of exactly the same size, we know instantly that the galena weighs more than the quartz. But why?

Two conditions determine the relative weights. First the nature of the atoms of which the minerals are composed, and second, whether these atoms are close together. The atoms of the very heavy metals, such as uranium and lead, are very heavy. Other things being equal, the compounds of these metals would be heavy. If, however, the atoms are widely separated in the compound, it may be light even though composed of heavy atoms. On the other hand, if the atoms are light, but they are densely crowded, the resulting mineral will be heavy. Corundum is a remarkable illustration of this, for while it is composed of aluminum and oxygen, both light elements, it is a comparatively heavy mineral.

If we take an empty box in the form of a cube and fasten a single shot in each of its eight corners, as shown in figure 153, even a child would know that it would not be nearly as heavy as if we fill it with shot, as shown in figure 154. These figures roughly illustrate one rea-



Figures 153, 154. Differences of Density

son for the differences in weight of minerals. A mineral in which the atoms are crowded, is spoken of as having a *high density*, while if the atoms are far apart, it would be said to have a *low density*.

Gravity is that attraction of the earth which tends to draw all bodies towards its center. If a body has a high density, this pull of the earth towards its center is much stronger than it is if the body has a low density. In other words, it is more difficult to lift it, or it is heavier.

It will be still heavier if the atoms of one of the elements of which it is composed are heavy.

It has been found that if a mineral is perfectly pure, the weight of two pieces of it of exactly the same size, say cubes of one inch square. is exactly the same. By comparing all minerals with water and ascertaining how many times as heavy as water the different minerals are. the mineralogist is able to record their relative weights, and because this is only another way of expressing the relative or specific pull of the earth for these different minerals, he calls the property *specific gravity*.

Various scientific methods of determining specific gravity have been devised. Mineralogists find it of immense service to know just what the specific gravity of different minerals is, as they are thus greatly aided in distinguishing between them. and no scientific description of a mineral is regarded as complete which does not give its specific gravity. While it is not possible to determine it accurately in the field, familiarity with their relative weights will help us much to distinguish between some of the common minerals. For example, if you find a white mineral with a good cleavage, it is more apt to be calcite than anything else, but if it is very heavy, it would be much more likely to be barite or corundum. If its hardness is tested with a piece of corundum and it is deeply scratched by it, it could not be corundum and probably would be barite.

If we were to examine all known minerals, we would find that more than half of them are from two to four times as heavy as water, or have a specific gravity between 2 and 4. Many of the metals and metallic minerals and many of those minerals which are compounds of the heavier metals, have a high specific gravity. On the other hand, the number of minerals whose specific gravity is less than water is very small. Ice is the only one that is common among solids, and it is because it is lighter than water that it will float on water.

The specific gravity of petroleum is less than that of water, so it floats on the surface of water, figure 155. In this instance all of the petroleum is above the surface of the water simply because petroleum is a liquid and its particles move freely upward, while in the case of the solid ice, the particles at the lower end are held down by the upper particles of the mass.

At least four fifths of all of the common minerals have a specific gravity of not over 4, while one third of the total number have a specific gravity of 3 or less. As our ideas of comparative weight are unconsciously based on those minerals which we handle most frequently, it is interesting to note that the three minerals we are most likely to meet in the field are of very nearly the same specific gravity. They are: common feldspar 2.57, quartz 2.65 and calcite 2.71. If we come across

a mineral which seems heavy, it will be because we unconsciously compare it with these common minerals. It is really surprising how slight a difference we can detect. Thus fluorite, whose specific gravity is 3.13, seems noticeably heavy if we compare pieces of the same size of fluorite and calcite. Our judgment is very apt to be at fault if the pieces we

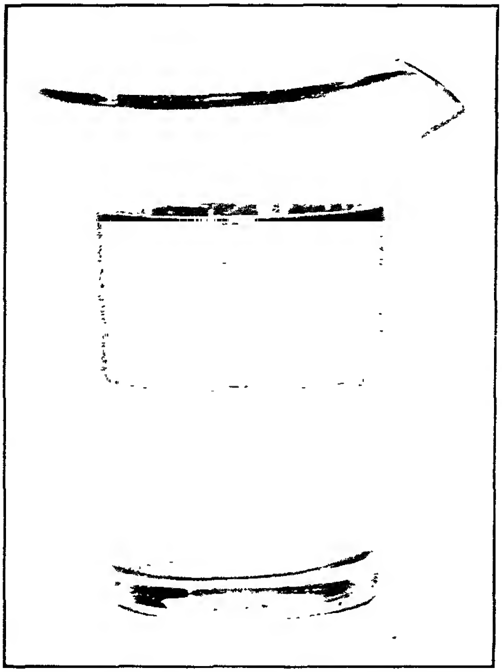


Figure 155. Petroleum Floating on Water Because Its Specific Gravity is Less

compare are of different sizes. We shall likely think that calcite is heavier than fluorite if the piece of calcite is two or three times as large as the fluorite. When the specific gravity rises above 4, we are not so easily deceived by differences in size and when it is 5 or more, we can scarcely make a mistake.

WHAT TO DO NEXT

If you have patiently studied the foregoing pages, it is believed that you have acquired a love for minerals and a desire to know much more about them. Thus far you have learned about minerals in general. What should you do next? The following suggestions should be helpful.

1st. Familiarize yourself with the minerals described in Part II, taking up one element at a time and seeking additional information wherever obtainable.

2d. Build up a permanent collection of your own by visits to mineral localities, by exchanges and by the purchase of specimens carefully selected to acquaint you with those about which you are studying.

3d. Make frequent visits to other collections, especially to those which are scientifically classified, and note particularly the characteristics of the minerals you are studying.

4th. Keep in constant touch with other earnest students and collectors and do all you can to make the meetings of your local mineral club interesting and worth while.

5th. Identify each of your specimens by their physical properties, with the aid of Appendix I.

6th. As soon as possible take up the study of chemistry and learn how to identify minerals by the aid of the blowpipe. Professor Dana's "Minerals, and How to Study Them" is an excellent guide. It will aid you too in further study of crystals.

If you adopt these suggestions you will derive increasing pleasure and profit from getting acquainted with minerals.

PART II

DESCRIPTIONS OF MINERALS

PART II

DESCRIPTIONS OF MINERALS

The minerals described in the following pages have been selected with great care as being those with which it is most important for the beginning student to become acquainted. It is not expected that any attempt will be made to commit to memory all of the data here given, nor would such a procedure be recommended even to the most industrious student. It is hoped, however, that the descriptions will aid in the identification of many minerals which may be met in the field and elsewhere and that their properties may become more and more familiar and be carefully noted on specimens in the student's own collection. If this be done, steady progress will be made in getting acquainted with minerals.

Some comparatively rare minerals have been briefly described, others being scarcely more than mentioned, in order that attention may be called to those of commercial importance. It is believed that this information will be of value to the prospector, mining man and visitors to mining regions.

It is very unlikely that many readers of this book will be so fortunate as to find diamonds in the field, yet the transcendent importance of this mineral justifies devoting more space to it than is accorded to many much commoner minerals which have no claim to our attention, except their abundance.

It is not usually possible to give brief descriptions of minerals, including the salient facts, and make them interesting. It is often true that much of interest can be found by searching for it. It is hoped, therefore, that beginners will use the following descriptions as the foundations upon which to base quests for the wealth of interesting information about many minerals and bring this to the meetings of clubs, where the enthusiasm of members over minerals will win new converts to study this most interesting of all the sciences.

CLASSIFICATION

The most scientific classification of minerals is one in which they are arranged according to their chemical composition and crystal form. This is the plan which has been adopted in practically all public museums and in many important private collections. This classification is set forth in Dana's "*System of Mineralogy*," which is the standard work of reference in the United States and is largely used all over the world. This monumental volume is the work of Professor Edward

Salisbury Dana of Yale University, the Dean of American mineralogists. An excellent college textbook in which this plan of classification is used is Dana's "*Textbook of Mineralogy.*"

The beginner in mineral study will find the Dana classification too difficult to understand until he acquires a fair knowledge of chemistry, crystallography, physics and higher mathematics. It has been thought best, therefore, to adopt for this book a classification of minerals based on the most important element in their make-up, with these elements arranged alphabetically. Those minerals which are of major importance as rock-formers are separately grouped at the end. This classification, by bringing together the ores of the metals, familiarizes the beginner with many sources of wealth about which he should be informed, and with the important ingredients of the rocks.

A. MINERALS GROUPED UNDER ELEMENT OF GREATEST IMPORTANCE

ALUMINUM MINERALS

Aluminum is the most abundant of all the metals in the crust of the earth, yet it does not occur in nature uncombined. Until 1886, its separation from its ores was attended with so much difficulty that the price of the metal was exceedingly high. In that year a young college student discovered that aluminum could be produced much more cheaply than ever before by passing a strong electrical current through a solution of its oxide in fused cryolite. If he had not been enough of a mineralogist to know of the comparatively rare mineral cryolite, and of its easy fusibility, his great discovery would probably never have been made.

Aluminum is the lightest and one of the most important of the commonly occurring metals, being only a little more than a third as heavy as iron. It is being freely predicted in scientific circles that the day is near at hand when it will largely replace steel in many industrial uses, such as automobiles, trucks and Pullman cars. Already it has largely superseded tin for household utensils, and many small useful and ornamental articles are made of it. It is extensively used in airplanes and structural work of various kinds. It will, however, have formidable competitors.

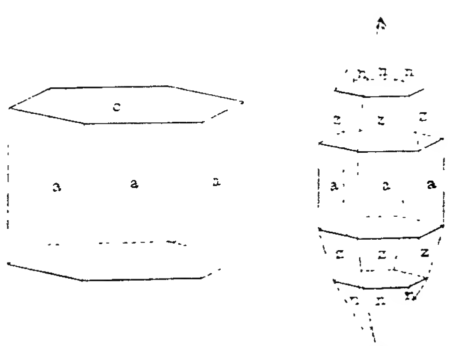
It is a silver-white metal, capable of a high polish. It oxidizes superficially, like copper, and the outer coating then protects the inner metal from further corrosion. Its alloys with copper and with magnesium are assuming major importance. Aluminum bronzes have much to commend them; they are nearly as hard as steel, can be cast, are beautiful and take a high polish.

Aluminum Ores. At present *bauxite* is the only mineral used as an ore of aluminum, but it occurs abundantly in a great many other minerals from which it is not so easily separated; of these the most important are *corundum, topaz, kaolinite.* Many rock-forming minerals, described in that section, are composed in part, of aluminum.

Bauxite is a hydrous oxide of aluminum, $Al_2O_3.2H_2O$, and contains, when pure, about 49% of aluminum. It occurs chiefly in two forms, first as a soft, earthy mass, second pisolitic (see page 92). *Hardness:* up to 3. *Specific gravity:* about 2.5. Ordinarily it contains much iron, replacing part of the aluminum, and then it has a red or reddish color, while, when pure, it is gray to cream-color, or sometimes brown. Great deposits of bauxite occur in the Southern states, and in many foreign countries. Its strange name is derived from Baux (Beaux), France, one of its well-known localities.

Corundum, though not used as an ore of aluminum, is an oxide, Al_2O_3, containing about 53% of this metal. It is a mineral with which the beginner should early become acquainted, not only because it is *number 9 in the scale of hardness,* page 31, and harder than any other mineral except diamond, but also because two of the most expensive precious stones, ruby and sapphire, are varieties of corundum. *Ruby* has a rich red color, the best gems being of "pigeon's blood" color. Paler tints of red or pink are not called ruby, but "pink sapphire." *Sapphire* includes all of the translucent to transparent kinds of all colors except deep red. Typical sapphire, however, is blue. *Emery* is a granular variety rendered black by the admixture of a large quantity of magnetite. *Ordinary corundum, "adamantine spar,"* is usually brown or gray.

Crystals are hexagonal, figure 156, sometimes tabular, more commonly in long prisms or barrel-shaped, figure 157. Often shows *parting* or



Figures 156, 157. Common Forms of Corundum Crystals

pseudo-cleavage into nearly cubical rhombs. When compact it is exceedingly *tough*. *Luster:* usually adamantine. Sometimes shows *asterism,* then called *star sapphire* (page 112). Ruby often shows magnificent crimson *fluorescence* under ultra-violet rays. *Specific gravity:* about 4., remarkably high for a compound of two light elements (see page 123).

Uses: valuable as an abrasive, but largely supplanted by carborundum, an artificial compound of carbon and silicon. When richly colored, highly prized as a gem.

Occurrence: The Orient, chiefly Burma, Ceylon and Siam, yields most of the best gems. Montana has produced some fine sapphires and many light-colored stones. Ordinary corundum abounds in North Carolina, Georgia, Canada and the Transvaal. Emery comes chiefly from Greece and Turkey; it was formerly mined at Chester, Massachusetts.

Topaz belongs to the great group of silicates, but in addition to silicon, oxygen and aluminum, a considerable quantity of fluorine is present, so that it is regarded as a "fluo-silicate of aluminum," its formula being $(AlF)_2SiO_4$.

It is not a common mineral, but in places where it does occur it is fairly abundant, usually in good *orthorhombic crystals* of prismatic development, figures 158–160, terminated by steep or flat faces, sometimes beautifully etched, figure 160.

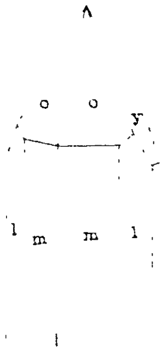


Figure 158

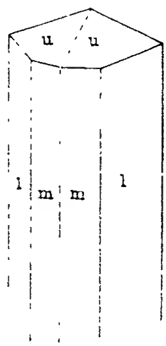


Figure 159

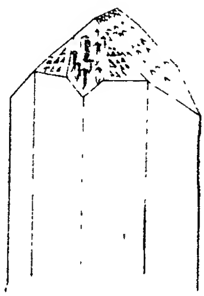


Figure 160

Figures 158–160. Common Forms of Topaz Crystals

Its perfect *basal cleavage*, and its lack of cleavage in other directions, serve to distinguish it from feldspar and other minerals which it sometimes resembles. Thin plates can be cleaved from crystals.

It is further distinguished by its great *hardness,* it being *number 8 in the scale of hardness*, page 31, so that it will scratch all common minerals

except corundum. Massive topaz, such as is found at Trumbull, Connecticut, is apt to be softer.

Its commonest *color* is white, or colorless, but often it is faintly tinted blue. Rich blue crystals of large size are found in Siberia, also magnificent transparent, brown crystals, this locality yielding specimens which rank among the finest of all mineral specimens. The "precious topaz" of Brazil, figure 159, is wine-yellow. It is sometimes altered to a delicate pink by heating. Some of the largest crystals known come from Brazil, but these are colorless or slightly tinted blue. Other localities yielding fine crystals of smaller sizes are Madagascar, Japan, Nigeria, Mexico, Maine, Colorado and Utah.

Its *luster* is vitreous and in rolled pebbles it is difficult to distinguish it from quartz without testing its hardness or cleavage. It is considerably heavier than quartz, its *specific gravity* being about 3.5.

Uses: If it were available in commercial quantities it would be a valuable abrasive. When transparent, it yields fine gems.

Kaolinite, china-clay, is a hydrous aluminum silicate, $H_4Al_2Si_2O_9$.

Hardness: 2. to 2.5. *Specific gravity:* about 2.6.

Form: Crystals of kaolinite are rarely seen and are almost microscopic, six-sided plates belonging to the monoclinic system. Ordinarily this mineral is found as a white, earthy mass, easily crushed and soiling the fingers.

Occurrence: Kaolinite is always the result of the alteration or weathering of feldspar. When water and the carbon dioxide of the air act on common feldspar it loses its luster, its cleavage disappears, it becomes soft and mealy. What has happened? The potassium unites with the carbon dioxide to form potassium carbonate, which, being soluble in water, is readily carried away by rains. The water combines with the aluminum and part of the silica to form kaolinite, while the remainder of the silica becomes quartz. This quartz often remains mixed with the kaolinite so that before it can be used it must be washed. The kaolinite thus formed may remain where it originally was or be transported by running water to the beds of streams, lakes or the ocean and there, mixed with various impurities, it is deposited in the quiet waters, finally becoming consolidated into clay.

Uses: Clay is plastic, when wet, and thus it is easily molded into bricks, roofing tiles, drain pipes, crockery, stoneware, and other objects These are then baked in kilns to dry and harden them. The better grades of china and porcelain are made from pure kaolinite, feldspar and quartz. The chief use of clay is for fire bricks; much is also used as a paper filler.

Kyanite, an aluminum silicate, Al_2SiO_5, has the same composition as two other minerals, andalusite and sillimanite. It occurs in thin, bladed crystals, usually in mica-schist. It is a remarkable illustration of the variation of hardness on different faces of the crystal, for on the broad sides the *hardness* is 5, while on the narrow faces it is over 7, harder than quartz. *Specific gravity* is about 3.6.

The name is from the Greek, *kyanos,* blue, alluding to its usual *sky-blue color,* which is often confined to the center of the blades, while the edges are colorless or white; green cyanite is also not uncommon. *Luster* is vitreous on the edges, often pearly on the flat sides.

Cleavage is easy parallel to the flat sides and somewhat more difficult parallel to the edges, while the blades are often apparently chopped off at the ends, producing a form which reveals the *triclinic* form of the crystals.

Kyanite sometimes is *transparent* and if it is at the same time of deep, rich-blue color, gems resembling blue sapphire may be cut from it.

Occurrence: It occurs plentifully in many localities, especially fine specimens being found in Switzerland and North Carolina.

Use: Kyanite has been used in the production of refractory materials.

Andalusite, another aluminum silicate, Al_2SiO_5, is remarkable for the regular arrangement of carbonaceous impurities inside the rough, rounded crystals of the variety *chiastolite.* This is shown in figure 161.

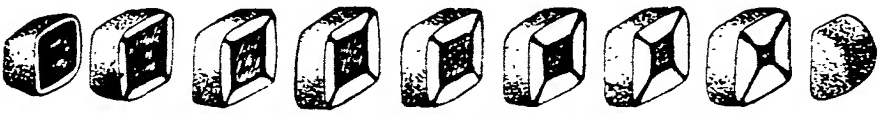


Figure 161. Chiastolite Crystal, Showing Carbonaceous Inclusions

As the mineral collector usually thinks of andalusite as a rough, ugly mineral, it is interesting to know that it occasionally occurs perfectly transparent and is cut into handsome, brown gems, with *hardness:* 7.5; *specific gravity:* 3.2. The massive mineral from California has recently been used in making spark plugs.

Sillimanite, a third aluminum silicate, Al_2SiO_5, has also been used in making spark plugs. It is usually in fibrous to columnar-massive *forms,* of dull brown or gray *color* and sometimes forms the major part of schistose rocks. Its *hardness* is 6 to 7; *specific gravity:* about 3.24.

Dumortierite is a boro-silicate of aluminum, whose exact formula is in doubt. It may be $8Al_2O_3.B_2O_3.6SiO_2.H_2O$.

Its *hardness* is 7; *specific gravity:* about 3.30; *luster:* vitreous.

It is usually in masses made up of fibers, or in columnar forms, some-

times developing into distinct, elongated, orthorhombic *crystals,* having a bright blue color, while in the fibrous form, a lavender to gray color is more common.

When first found, in France, in 1881, it was regarded as a rare mineral. Later it was discovered at the Harlem Speedway, New York City, then in Arizona, California and other localities, until now it is considered a fairly common mineral. Finally large deposits were found in Nevada and it was mined by the carload for the manufacture of spark plugs.

Spinel is an oxide of aluminum and magnesium, $MgAl_2O_4$. *Hardness:* 8, exceeded by but few minerals; *specific gravity:* about 4.0.

Crystals: isometric, usually in octahedrons, sometimes twinned, figure 103, and often modified by the dodecahedron, figure 162, and occasionally the trapezohedron. Very rare in any other forms.

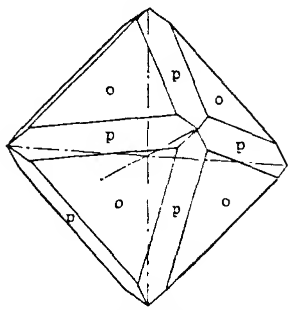


Figure 162. A Common Form of Spinel Crystals

While a careless observer might see spinel but rarely, a trained eye will find it frequently in many rocks in minute black crystals, distinguished from magnetite by not being magnetic. It is especially plentiful in the limestone region of Orange County, New York and Sussex County, New Jersey. Fine crystals occur in Canada, and very bright little octahedrons may frequently be found in the masses ejected from Vesuvius. The most important localities, however, are in Ceylon, India, and Siam, for here occur the beautiful *ruby spinel*, the deep blue, purple, lilac, green, yellow, and other attractive colors, and as they are often transparent, truly magnificent gems are obtained, sometimes rivaling the true ruby.

Chrysoberyl is a rare compound of aluminum and beryllium oxides, $BeAl_2O_4$. It is one of the very *hardest* of minerals: 8.5, being inferior only to corundum and diamond. Because it is also found *transparent* and is rare, it is prized as a gem stone. The best gems are of a golden

yellow color, whence its name, from the Greek words *chrysos,* golden and *beryllos,* beryl. The variety, *alexandrite,* figure 163, from Siberia or Ceylon, which has a grayish-emerald green color by natural light, has the remarkable property of appearing a peculiar "columbine red" by artificial light. It is one of the most expensive of all gems.

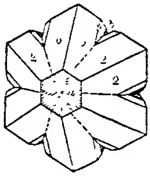


Figure 163. Chrysoberyl, variety Alexandrite

Ordinary chrysoberyl, such as is found in Maine, at Haddam, Connecticut, and elsewhere, is usually of a yellow *color,* but rather dull. *Specific gravity:* about 3.7.

Chrysoberyl *crystals* are orthorhombic and tabular and are frequently twinned and striated.

Pyrophyllite is a hydrous aluminum silicate, $H_2Al_2(SiO_3)_4$.

It is soft, its *hardness* ranging from 1 to 2. *Specific gravity:* 2.85.

It is distinguished by its radiated-lamellar *structure* and the ease with which small fragments will exfoliate or spread out into fan-shaped forms, several times as large as the original, when heated in a flame. There is, however, a massive variety which does not have these characteristics and can only be distinguished from massive talc by chemical tests. This has the same *uses* as talc.

The most common *color* is yellowish-white to brownish-white, but at Zermatt, Switzerland, there is a charming green variety. Badin, North Carolina yields beautiful material, as also Graves Mountain, Georgia and Mariposa County, California.

Turquois is a hydrous phosphate of aluminum and copper, possibly $CuO.3Al_2O_3.2P_2O_5.9H_2O$.

It is almost always in thin seams and irregular masses; *opaque,* with *color* bright robin's-egg blue, or bright green to greenish-gray. Its *hardness* is 5 to 6; *specific gravity:* about 2.7.

It was known and used by the ancients as a *semi-precious stone,* their material largely coming from Persia. The Mexicans and Indians derived their supply from the old mines near Santa Fe, New Mexico. Fine material also occurs elsewhere in New Mexico and Arizona.

The name is derived from the French name of Turkey, through which country the merchants brought their supplies.

ANTIMONY MINERALS

Antimony is classified, chemically, as a *semi-metal,* because of certain compounds it forms and also because it is a poor conductor of heat and electricity. It has, however, a brilliant metallic *luster* and is *opaque.* It is not much lighter than iron, its *specific gravity* being 6.7. Its most important *uses* are for automobile bearings and in making the alloy known as type-metal, for which it is invaluable owing to its peculiar property of expanding on cooling.

Native Antimony is a rare mineral, found in this country in nodules in Kern County, California, and at but few foreign localities.

Stibnite is a sulphide of antimony, Sb_2S_3. Its *hardness* is only 2, so that it may be scratched with the finger nail and it will soil paper. *Specific gravity:* about 4.6.

Its *luster* is metallic, and on fresh surfaces unusually brilliant; *color:* bluish-gray, but it becomes dull by tarnishing.

Its usual *occurrence* is in bladed masses, though elongated orthorhombic *crystals* are not uncommon. These are often clustered irregularly, or in radiating groups, figure 118. Crystals are commonly half an inch to an inch in length, but magnificent crystals and groups were found many years ago in Japan with individual crystals 18 inches or more in length, and it is not unusual to see Japanese stibnite crystals of three to eight inches in length. Very fine specimens of much smaller sizes have also come from near Hollister, California, figure 164, and splendid

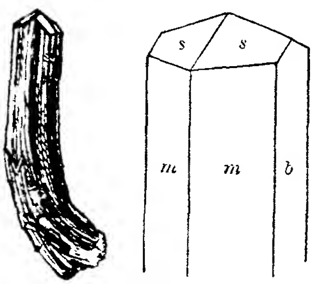


Figure 164. Stibnite, near Hollister, California

groups from Roumania. The commercial supply, however, comes largely from China.

The *cleavage* of stibnite is very perfect parallel to one of the vertical faces of the crystals. It is thus distinguished from galena.

Another distinguishing property, which would be overlooked by a collector who only looks at his specimens, is the ease with which stibnite

fuses, its *fusibility* being taken as *number 1 in the scale of fusibility.* Try holding a small fragment in any flame and see how quickly it melts.

Stibnite is much the commonest and most important ore of antimony.

Other Antimony Minerals. Considerable deposits of oxidized antimony ores occur in Algeria, chiefly the minerals *valentinite, senarmontite,* and *cervantite.* These are found elsewhere in limited quantities.

Antimony is also an essential part of at least fifty other minerals, including such valuable or important species as *bournonite, pyrargyrite, tetrahedrite, stephanite, polybasite* and *bindheimite.*

ARSENIC MINERALS

Arsenic is closely related to antimony in its chemical reactions and is classed as a semi-metal. Its luster is not nearly so brilliant as that of antimony, and it is considerably lighter, specific gravity being 5.7. Its most important use is in hardening certain alloys. Its oxide, popularly called "arsenic," is a white powder, and is used in enormous quantities as an insecticide, weed killer, preservative of bird skins and furs and in making enamels and opaque glass. Calcium arsenate is extensively used in combating the boll weevil, and Paris green in fighting potato bugs.

Native arsenic is quite rare and there are no important occurrences in the United States. Its *luster* is metallic; *color:* tin-white, but it quickly tarnishes to a dull gray. It is usually granular with a mammillary or botryoidal *form.*

Ores of arsenic are *realgar, orpiment,* and *arsenopyrite.*

Realgar is one of the arsenic sulphides, AsS. Its *hardness* is only 1.5 to 2; *specific gravity:* 3.56. It is said to be *sectile* (see page 36), but you will certainly find crystals *brittle.* Its gorgeous red *color* makes it conspicuous in any collection, but beware of leaving it exposed to the light, for it will soon change to a yellow powder. Its *luster* is resinous. Its *crystals* are monoclinic. The best come from Roumania, but most beautiful specimens occur in Nevada and elsewhere in the Western states.

Orpiment is another arsenic sulphide, As_2S_3. Its *hardness* is 1.5 to 2; *specific gravity:* 3.45. It is quite *sectile* (see page 36) in thin cleavages. *Crystals* are monoclinic, but rare. It is generally found in crystalline masses, often, as at Manhattan, Nevada, associated with realgar, the combination of the red realgar with the bright lemon-yellow to orange orpiment being most pleasing.

It has an easy *cleavage* parallel to one of the side faces of the crystal and can often be split into thin leaves which may be bent at will. The *luster* on the cleavage face is pearly, but elsewhere it is resinous.

Arsenopyrite, also called mispickel, or arsenical pyrites, is a compound of iron with sulphur and arsenic, technically known as iron sulpharsenide, FeAsS.

It has a hardness of nearly 6, and a *specific gravity* of about 6.

Luster is metallic. *Color:* grayish. silver-white. *Streak:* dark grayish-black. *Opaque.*

It forms orthorhombic *crystals* of very characteristic wedge-shaped forms, as at Freiberg in Saxony, and Sulitjelma in Norway; but it is usually massive.

It is the chief ore of arsenic and occurs in a great many localities. One of the most important occurrences is at Deloro, Ontario, where it is gold-bearing.

It may be distinguished from pyrite by its whiter color and the fact that when rubbed vigorously or heated it gives off a garlic *odor* (poisonous).

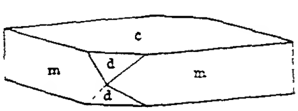
Other arsenic minerals. There are many other minerals in which arsenic is an essential constitutent. It is often combined with sulphur and a metal. as in *proustite*, or with oxygen and a metal in the important group of *arsenates*. of which *mimetite*, *olivenite* and other copper arsenates and *erythrite* are illustrations.

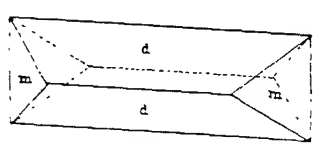
BARIUM MINERALS

There are but two important barium minerals, *barite* and *witherite.*

Barite, or "heavy spar," is barium sulphate. $BaSO_4$. Its most prominent characteristic is its *specific gravity*. 4.5. which is much above the average of nonmetallic minerals and serves to distinguish it at once from marble or dolomite which its granular form sometimes suggests.

It forms orthorhombic *crystals* of many different types. figures 44, 47, 165, 166. but they are usually tabular.





Figures 165, 166. Common Forms of Barite Crystals

It has perfect *cleavage* parallel to the base and the prism. thus forming cleavage rhombs not unlike those of calcite. but different in angle.

Fracture: uneven. *Tenacity:* brittle.
Hardness: 2.5 to 3.5. *Luster:* vitreous.
Color: colorless to white, yellow, blue, green. *Streak:* white.
Transparent to translucent in crystals; masses, opaque.

Occurrence: It is a common and widely distributed mineral, often found in veins in limestone and also as a gangue mineral in metallic veins. Commercial deposits are numerous. Famous specimen localities are in the Frizington region, North of England, figures 167, 168, also in

Figure 167. Barite on Dolomite, Frizington, Cumberland, England

Roumania and other European localities, at Cheshire, Connecticut and in South Carolina. Beautiful brown, stalactitic barite comes from Derbyshire, England, figure 169.

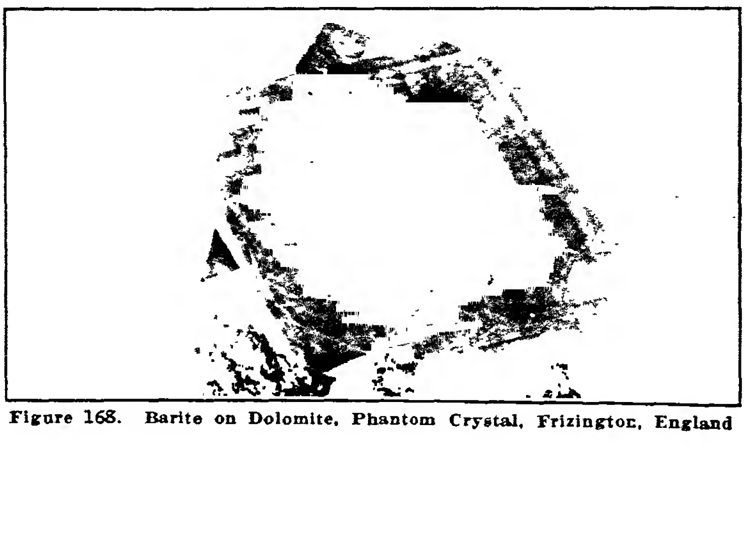


Figure 168. Barite on Dolomite, Phantom Crystal, Frizington, England

Uses: Its chief use is as a pigment, but it has many applications in chemistry, and is of great importance in the refining of sugar.

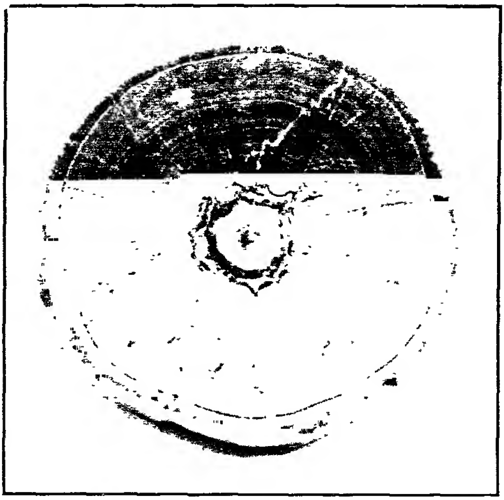


Figure 169. Barite, Cross Section of Stalactite, Newhaven, Derbyshire, England

Witherite is barium carbonate, $BaCO_3$. It is a comparatively rare mineral, with *hardness:* 3.5; *specific gravity:* 4.3; *color:* white. Usually in *crystals* of pseudo-hexagonal form, with pyramids piling up one on top of another, figure 170. Its best locality is at Hexham in the North of England.

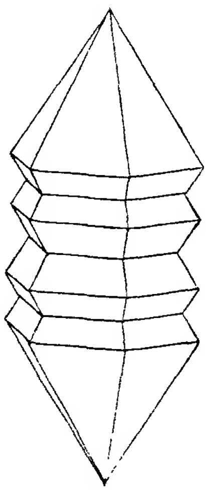


Figure 170. Witherite, a Form Common in England

BERYLLIUM MINERALS

Beryllium (also called Glucinum) is a silver-white metal with a *specific gravity* of only 1.9, considerably lighter than aluminum, whose specific gravity is 2.6. With the exception of lithium, it is the lightest of all the metals, and for this reason much experimentation has been made to utilize it in airplanes.

Beryl, the only common beryllium mineral, is a beryllium-aluminum silicate, $Be_3Al_2Si_6O_{18}$. Its *hardness* is 7.5 to 8, exceeded by only three other minerals. *Specific gravity:* 2.70.

Form: Almost always it is found in simple hexagonal prisms, figures 171, 173, but magnificent specimens are to be seen in large collections with one or more pyramidal faces, figure 172, replacing the usual flat termination.

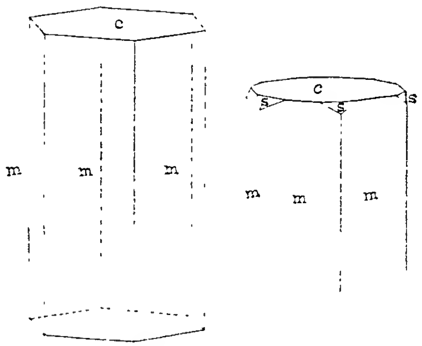


Figure 171, 172. Common Forms of Beryl Crystals

Its *cleavage* is not distinct. *Fracture:* usually conchoidal or uneven. *Tenacity:* brittle.

Streak: white, but owing to its great hardness not obtainable with a streak plate, but only by powdering. *Transparent* to nearly opaque. *Luster:* vitreous to greasy. *Color* varies greatly and leads to the separation of important varieties. *Common beryl* is usually pale green, but may be colorless or white. *Aquamarine*, as its name implies, is the color of sea-water, which varies from bluish-green to greenish blue. It is customary, however, to include all shades of blue under aquamarine and also all greens except the deep, rich green of the variety called *emerald*, whose color is due to the presence of a small percentage of chromium. There is also the beautiful *golden beryl*, of various shades of yellow, and pink beryl, which has been called *morganite*.

Occurrence: The characteristic mother-rock of beryl is pegmatite, figure 173, or less commonly mica-schist. Common beryl is found in crystals of enormous size; one in the museum of the Boston Society of

Natural History measures 40 inches in diameter and is 42 inches high, and even this is only a piece of a crystal originally nine feet long. An emerald found in North Carolina was nine inches long and even larger crystals have been found in the Russian mines. In Brazil aquamarines have been found of mammoth sizes.

Figures 173. Beryl Crystals in Pegmatite, Topsham, Maine

Uses: Emerald is the most valuable of all gems and is one of the four *precious stones*. The beautiful morganite is much rarer, though not so highly prized. Golden Beryl gems are quite popular, but are not abundant.

Beryl is *distinguished* from apatite, which it often much resembles, by its great hardness.

Other beryllium minerals. While there are no common beryllium minerals except beryl, several species are worthy of mention.

Chrysoberyl, which contains about 20% of beryllium oxide, is described on page 135.

Phenacite is a beryllium silicate, Be_2SiO_4, containing 45.55% of beryllium oxide. It has a *hardness* of 7.5 to 8, equal to that of beryl; *specific gravity:* 3. It is *colorless* and often *transparent,* in which case it yields gems of considerable beauty, the finest coming from the Urals. The *crystals* belong to the rhombohedral division of the hexagonal system and are often lenticular in shape. The most prolific American localities are in Colorado, figure 174, but the crystals are small compared with those of the Urals and Norway.

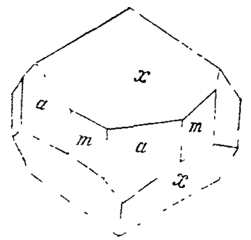


Figure 174. Phenacite, a Common Form at Mount Antero, Colorado

Bertrandite, a hydrous beryllium silicate, is sometimes associated with phenacite.

Gadolinite is a beryllium-iron-yttrium silicate.

Some fifteen other rare beryllium minerals are known.

BORON MINERALS

Boron: The element Boron is not found free in nature and has no practical applications. It is, however, present in the common mineral, *tourmaline,* and a considerable number of other less abundant minerals and some of its compounds are of great economic importance.

Sassolite is the name given to the naturally occurring boric acid, H_3BO_3, extensively used as an eye wash. It is a rare mineral, found in tiny white scales in the lagoons of Tuscany, Italy.

The Borates include a group of about thirty minerals, mostly quite rare, in which boron and oxygen are combined with one or more metals, and sometimes with considerable water. Several of them are abundant in certain localities, especially in California and Nevada and are worthy of the beginner's attention owing to the great importance of borax in everyday life.

Borax, hydrous sodium borate, $Na_2B_4O_7.10H_2O$, is better known in the laundry and to the chemist than to mineral collectors. It occurs, however, in considerable abundance dissolved in the waters of certain

alkaline lakes, whose gradual evaporation causes it to separate out as white, monoclinic crystals, figure 175, having forms similar to those of pyroxene. It is soluble in water.

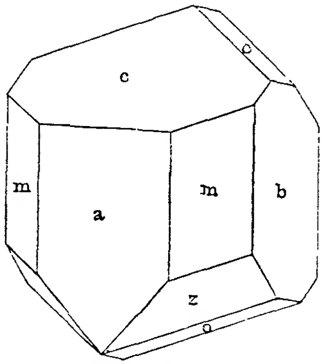


Figure 175. Borax Crystal

Colemanite, hydrous calcium borate, $Ca_2B_6O_{11}.5H_2O$, for many years was the most important source of borax. *Hardness:* 4 to 4.5. *Specific gravity:* 2.42. *Cleavage:* distinct in two directions. *Tenacity:* brittle. *Color:* yellowish or milk-white to colorless. *Luster:* vitreous in crystals, almost dull in massive form. *Streak:* white. *Transparent* to nearly opaque. *Form:* monoclinic. Usually in groups of beautiful prismatic crystals, $\frac{1}{4}$ to $\frac{3}{4}$ inch, sometimes much larger, often lining geodes in the massive mineral. *Occurrence:* known only in the borax deposits of California and Nevada.

Ulexite, hydrous calcium-sodium borate, $CaNaB_5O_9.8H_2O$, is a fairly common associate of other borax minerals, not only in the Pacific Coast borax region, but also in Chile, Argentina, Nova Scotia and elsewhere It is usually in masses of fine, soft, white, silky fibers.

Kernite, hydrous sodium borate, $Na_2B_4O_7.4H_2O$, was entirely unknown until 1926, when it was accidentally discovered in drilling a well in Kern County, California. A vast deposit of the mineral has been found and it is now the principal source of borax. The mineral is soluble in water and by simply evaporating the solution borax crystallizes out. Referring to the formulas of these two minerals above, it will be noted that the only chemical difference between them is that borax has ten molecules of water and kernite has four. The weight of the borax secured is thirty-nine per cent greater than the kernite dissolved.

Hardness: 3. *Specific gravity:* 1.95. *Tenacity:* brittle.

Form: monoclinic, but usually in fibrous masses showing excellent

cleavage. Luster: vitreous to pearly. *Transparent* to translucent. *Color:* white to colorless.

The white coating which is frequently seen on kernite and which forms the decomposition product of borax is the mineral *tincalconite,* another sodium borate, with five molecules of water.

Every collector should visit the California borax region, if possible.

CALCIUM MINERALS

Metallic calcium has no important uses in the arts and is rarely seen except as a chemical curiosity, but its compounds are of transcendent importance, including three of the minerals in the scale of hardness, *calcite, fluorite,* and *apatite;* and also *aragonite, gypsum, anhydrite,* and other important minerals, while *dolomite* contains both calcium and magnesium. It is also a common ingredient in many rock-forming minerals.

Calcite is calcium carbonate, $CaCO_3$. It is by far the most important calcium mineral. When pure it is colorless and transparent. Clear calcite, called Iceland spar, exhibits remarkable *double refraction,* as shown in figure 143, and explained on page 110.

Another striking property of calcite is very perfect rhombohedral *cleavage,* figures 109, 110, noted on page 78. While it has a conchoidal *fracture,* it is rarely seen owing to the ease with which the mineral cleaves.

It is *number 3 in the scale of hardness,* page 31, and has a *specific gravity* of about 2.72.

Calcite *crystals* are classified in the rhombohedral division of the hexagonal system (see page 54). They occur in an almost endless variety of forms and combinations, more faces having been described on calcite crystals than on any other mineral, literally hundreds of them. Simple rhombohedrons, figure 176, such as are yielded by cleaving any type of crystal (see page 78), are rare in natural crystals. The

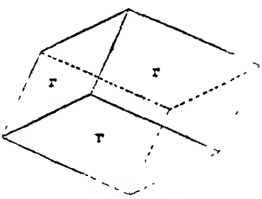


Figure 176

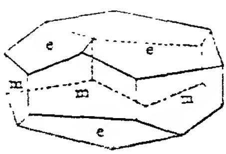


Figure 177

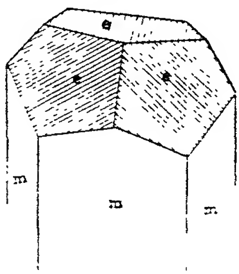


Figure 178

Figures 176–178. Typical Forms of Calcite Crystals

flat rhombohedron *e*, figure 62, with prism *m*, is shown in figures 177, 178. One of the commonest forms of calcite crystals, the scalenohedron, was described on page 55. The scalenohedron, combined with the prism, and rhombohedron *e*, is shown in figures 66 and 179. Is it not wonder-

Figure 179. Calcite, Group of Crystals, Bigrigg Mine, Cumberland, England

ful that no matter how complex a calcite crystal may be there are never any other fundamental forms present except rhombohedrons, scalenohedrons, pyramids, prisms and the base. Twins (see page 72) of calcite are often of great beauty and are not uncommon. Figure 182 shows one from Egremont, England.

While calcite is abundant in crystals, it is much more plentiful in other forms, and there are many of them. By far the most important variety is *limestone* of which there are several strikingly different types.

Coquina, found so abundantly near Saint Augustine, Florida, that it is available as a building stone, is one of the most instructive of the varieties It is little more than a mass of fossilized shells. The *pearly shell limestone* of the canyon at Rochester, New York is a harder, more

Figure 180. Calcite, Golden Crystal, near Joplin, Missouri

compact limestone. Most limestones are made up of the more completely altered remains of mollusks, corals, crinoids, and other lime-secreting, marine life. These accumulate in layers or "strata" on the ocean bottom and are slowly cemented into a solid rock. Layer by layer, they are built up through millions of years into great beds hundreds of feet thick. Such rocks, composed largely of calcium carbonate, but often with

impurities of silica or clay, form great mountain ranges in many parts of the world.

When subjected to heat and pressure, common limestones are changed or "metamorphosed" into crystalline limestone, called *marble.* Or, it

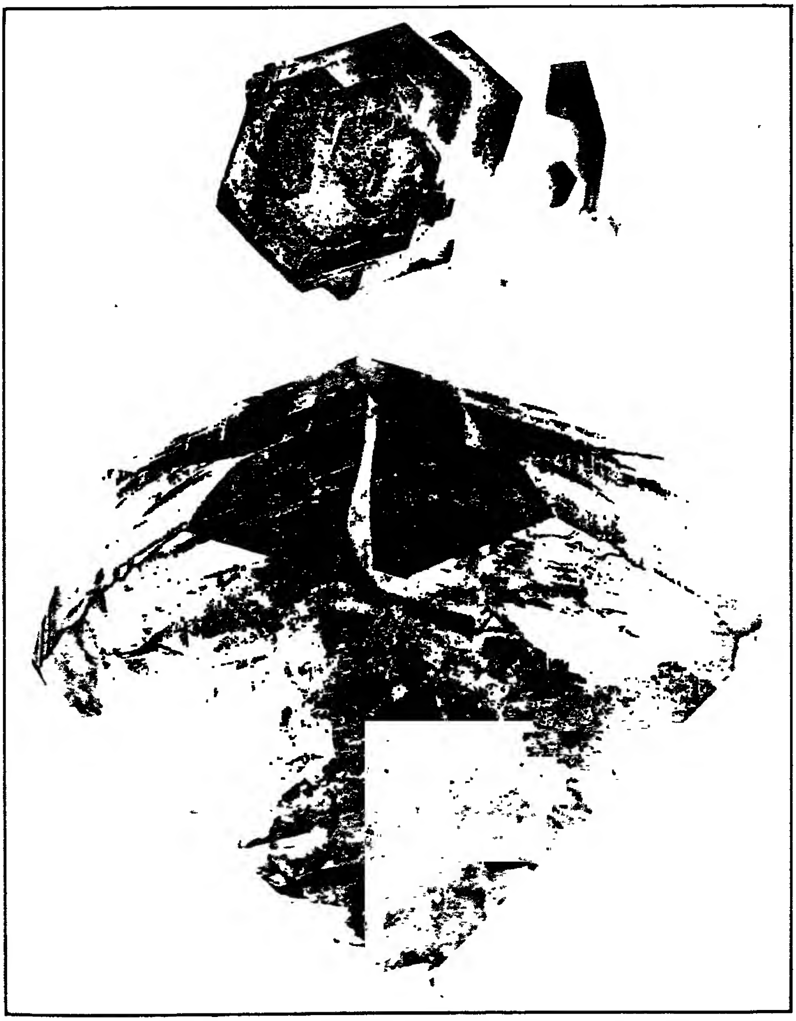


Figure 181. Calcite, Tabular-Hexagonal Crystals, Andreasberg, Harz, Germany
Figure 182. Calcite Twin, Egremont, Cumberland, England

may be, they are slowly dissolved by water carrying carbon dioxide and redeposited in caves, figure 132, in icicle-like forms, called *stalactites* and *stalagmites.* When redeposited by streams or springs in large quantities *travertine* results, or, if in smaller quantities coating leaves.

twigs or moss, *calc tufa* is produced. The study of these formations is wonderfully interesting.

Another curious type of calcite, *oolite,* figures 127, 128, is described on page 93. It occurs in great beds in England, Indiana, and other sections, and is one of the most important building stones.

Chalk is a soft, white, compact limestone composed largely of the shells of minute, marine organisms. Do not confuse true chalk with the so-called chalk of the class room which is made of gypsum.

There are many other varities of calcite, some of which you are quite likely to meet on your hikes and there is much to be learned about them. You could have a large collection of nothing but calcite specimens, for the variety and beauty of the crystals and of other types, as well as the showy polished marbles, are almost beyond belief. Calcite is certainly a charming mineral.

Chemically, calcite is calcium carbonate $CaCO_3$. A drop of acid will cause any variety to fizz, due to the liberation of the carbon dioxide. You can distinguish calcite from feldspar instantly by this simple test and then confirm it by testing the hardness, calcite being 3, while feldspar is 6.

Aragonite has the same chemical composition as calcite, calcium carbonate, $CaCO_3$, but crystallizes in the orthorhombic system instead of the rhombohedral.

Its *hardness* is 3.5 to 4, while calcite is 3, and its *specific gravity* is somewhat higher, 2.9 instead of 2.7.

It is usually quite different in *form*, though at times it is difficult to distinguish between them at sight. If the specimen under consideration shows rhombohedral cleavage it is certainly not aragonite, for it has *no cleavage*. It frequently forms in *transparent*, spire-shaped crystals and these sometimes are found on the outside of calcite stalactites. At Frizington, England beautiful groups of spire-shaped crystals occur, figure 183; twin crystals much resembling hexagonal prisms are found in the Pyrenees Mountains, while magnificent groups of large, colorless crystals occur in Sicily and Czechoslovakia.

Flos-Ferri, "flower of iron," picturesquely so named because of its occurrence in some iron mines, is shown in figure 124. It often is in masses made up of interlacing stems of snow-white color, which are typical illustrations of the so-called coralloidal *form*, (see page 92). The best material is from Austria.

Aragonite is frequently found in more or less radiated, coarse-fibrous to columnar masses, sometimes colored blue by aurichalcite, as near Tucson, Arizona.

Fluorite is calcium fluoride, CaF_2. It is a very interesting mineral from several standpoints. We have already made its acquaintance as *number 4 in the scale of hardness* (page 31), and we have seen that it has very well developed *octahedral cleavage* (page 78).

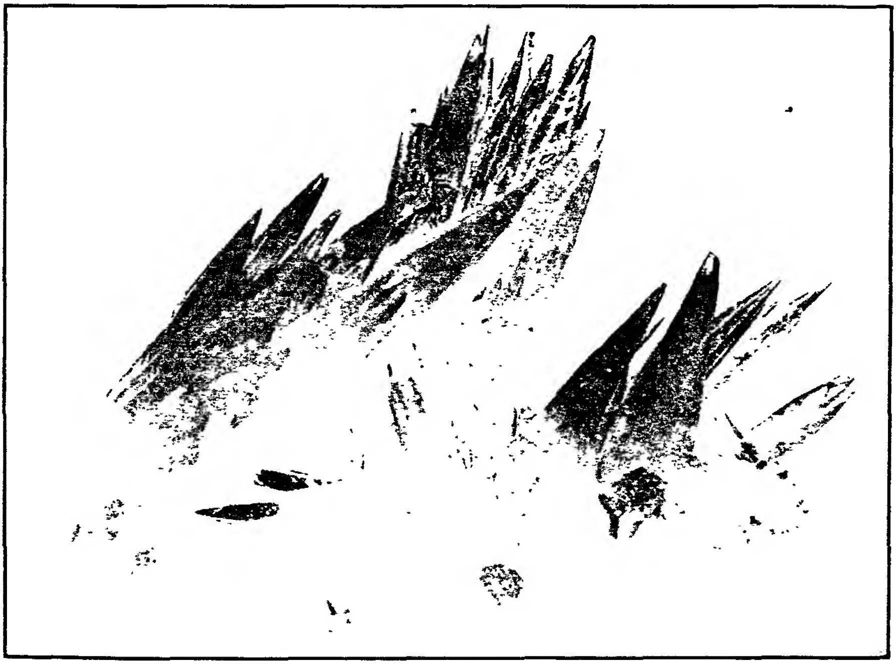


Figure 183. Aragonite, Radiating Crystals, Frizington, Cumberland, England

Chemically, fluorite is of interest because it shows us a point in reference to the electron theory (page 21) which we have not yet noticed. Fluorite is a compound of calcium and fluorine; calcium has two free electrons in the fourth ring; fluorine has seven in the second ring. We have seen (page 25) that the atoms of such elements respectively part with their free electrons and borrow or take on electrons from other atoms. In this case the calcium atom has two to give, but fluorine wants but one; therefore, it is necessary for there to be two fluorine atoms in order to use the two free electrons of a single calcium atom. The formula of fluorite thus becomes CaF_2, and the atoms of the metal calcium unite with those of the gas fluorine to form the beautiful non-metallic mineral, fluorite, which adorns so many collections.

Another property of fluorite, which is so notable that the mineral has given its name to the property, is *fluorescence*. This is explained on page 113. Some fluorite also shows *phosphorescence* (see page 115). The exhibition of these properties by fluorite is often very striking.

Its *specific gravity* is 3.18.

The name, fluorite, is derived from the Latin *fluere,* flow or flux, because it aids other minerals to become liquid. Because of this fact the mineral is extensively employed as a flux in open hearth furnaces. It is also of great importance in making hydrofluoric acid, used for etching glass, and it has other important uses.

Fluorite is a widely distributed and fairly common mineral. It occurs in isometric crystals, usually in cubes which are very often twinned as shown in figures 104, 184. Other forms are much rarer. It is abundant in veins as a coarse-granular material.

Figure 184. Fluorite, Group of Cubical Twins, Weardale, Durham, England

Most beautiful specimens have been found in great abundance in the iron mines of Northern England in groups of green, purple and wine-yellow crystals. Pink octahedrons come from Switzerland and are highly prized for their beauty and rarity. The chief commercial supply in the United States is in Southern Illinois and northern Kentucky. It occurs abundantly in Colorado and New Mexico. Cubes of mammoth size formerly came from Macomb, New York. Many other localities all over the world yield fine specimens or are of commercial importance.

Apatite is a phosphate of calcium, but with the addition of either calcium fluoride or calcium chloride, the former being much the most abundant. Miners always call it "phosphate."

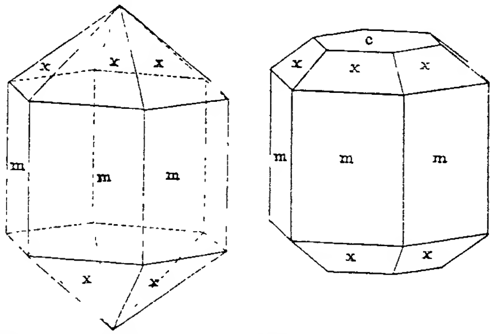
Hardness: No. 5 in the scale of hardness. Specific gravity: 3.2.

Luster: vitreous to sub-resinous.

Color: usually green or brown, but sometimes yellow, violet, blue, white or colorless. *Streak:* white. *Transparent* to opaque.

Cleavage: basal, but not prominent. *Tenacity:* brittle.

Forms: crystals, hexagonal, usually in rather long prisms terminated by pyramids, figure 185, and often the base, figure 186; more rarely in tabular crystals and then more complex.



Figures 185, 186. Common Forms of Apatite Crystals

Occurrence: It is abundant in rocks of all classes, scattered in small crystals. As these weather, the ingredients are washed down, part remaining to enrich the soil, while other portions eventually reach the sea and are built up into parts of living organisms. The mineral was formerly mined in Canada, but it has been replaced by the phosphorite found in Southern and Western States and elsewhere. Fine, large crystals, of the coarser types, are found abundantly in various Canadian localities, while the delicate and beautiful specimens of smaller sizes are chiefly from central Europe, Maine and Mexico.

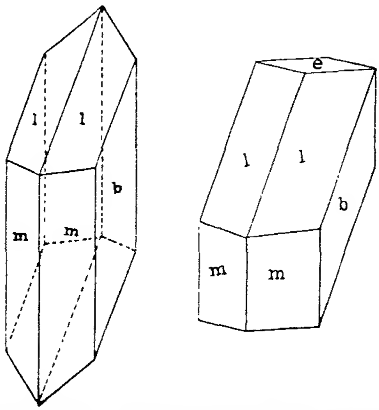
Identification: distinguished from beryl, which the larger crystals often closely resemble, by its inferior hardness and solubility in either hydrochloric or nitric acid.

Uses: as a fertilizer.

Collophanite is a hydrous calcium phosphate, $Ca_3(PO_4)_2.H_2O$. It includes the many forms of "phosphate" rocks embraced under the general term "phosphorite." This material is more properly regarded as a rock than a mineral. The nodular phosphates of the Southern States, the "pebble phosphates" of Florida and other types found in the Southern States as well as the vast deposits of oolitic "phosphate" in Wyoming and other Western States belong under collophanite. They are of enormous value as fertilizers.

Gypsum, hydrous calcium sulphate, $CaSO_4.2H_2O$, is found in several very different forms.

Selenite, number 2 in the scale of hardness, page 31, with *specific gravity:* 2.32, is the variety occurring in *monoclinic crystals,* most commonly of the types shown in figures 49, 187, 188. Its *cleavage* is developed in three directions, yielding rhombic plates. The largest cleavage face has a pearly *luster,* while the other faces are sub-vitreous and show



Figures 187, 188. Common Forms of Gypsum Crystals

respectively conchoidal and fibrous *fracture.* Its *tenacity* is remarkable, it being both flexible and sectile (page 36). Selenite is *transparent* and usually *colorless.* *Streak* is white. Mammoth crystals, some five feet or more, have been found. Among its most celebrated localities are Utah, Mexico, Sicily and France. Figure 190 shows a rosette from Texas.

Satin spar is a fibrous variety having a charming silky or satiny *luster.* Its *color* is usually white or pale yellow. It is popular at Niagara Falls and other tourist resorts for cheap jewelry and ornaments. The best material comes from England, Siberia and Nevada.

Alabaster is a fine-grained, sub-translucent variety, extensively used in Italy for statuary and other carvings.

Rock-gypsum, "plaster-stone," is a medium-coarse to fine-grained variety which occurs in beds of great thickness and is regarded as a rock.

Occurrence: Gypsum forms great beds in many rocks and is often associated with halite. *Uses:* The most important use is in the building trades and as "Plaster of Paris."

Anhydrite is calcium sulphate, $CaSO_4$. It usually occurs in fine-granular masses of sugar-like texture: white, gray or pale blue. *Hardness:* 3 to 3.5 and thus distinguished from similarly appearing varieties of gypsum, whose hardness is 2. *Specific gravity:* about 2.9. *Crystals:*

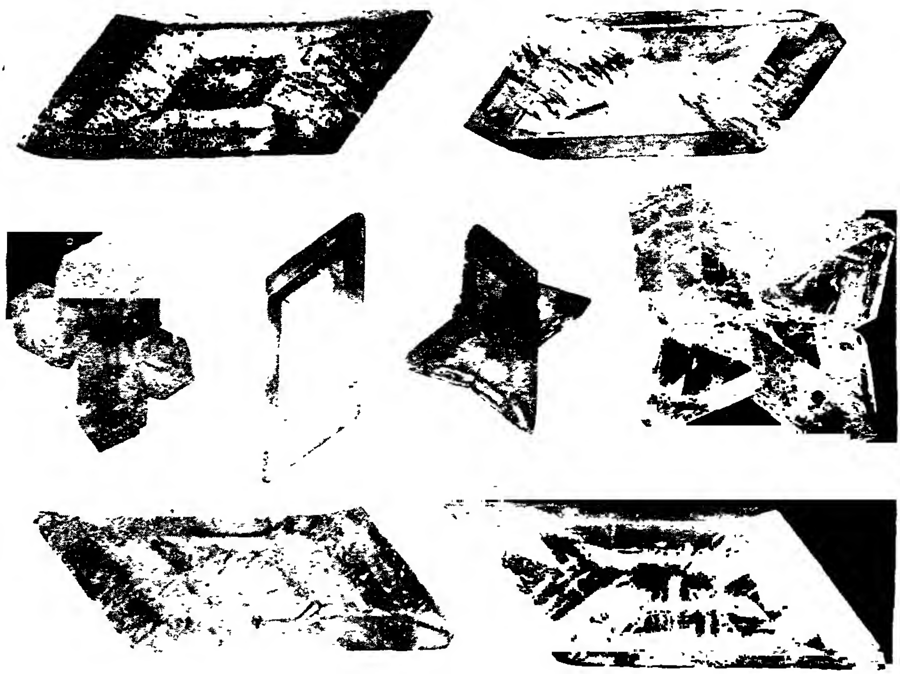


Figure 189. Gypsum, variety Selenite, Crystals, Ellsworth, Ohio

rare, readily yielding *cleavages* of cubic appearance. Often associated with gypsum in extensive beds.

Dolomite is described under Magnesium minerals on page 187.

CARBON MINERALS

Carbon, the Most Important of the Elements

It is safe to say that carbon is the most important of the elements. If it were judged merely by the two forms in which it occurs as distinct minerals in nature, it would not be accorded the highest rank among the elements, even though one of them is the matchless gem, diamond. *Carbon, however, forms fully 200,000 compounds*, a far greater number than are formed by any other element except Hydrogen. They make our

fuels—coal, oil and gas; much of our foods and clothing, many drugs, dyes, explosives. Carbon is used in pencils, printer's ink, lubricants, crucibles and almost countless other products upon which we are dependent for the necessities and comforts of life. How could we get along without steel? Yet it could not be produced unless carbon were added

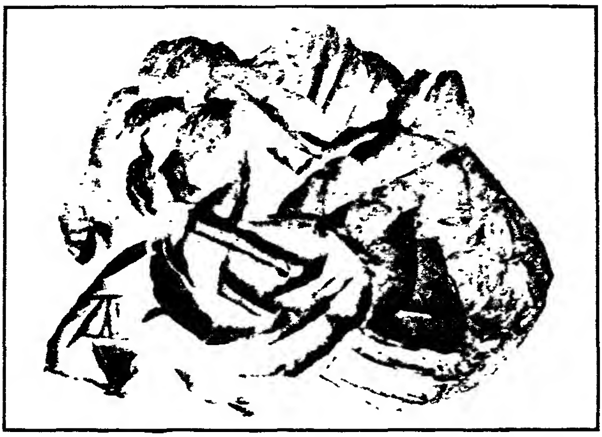


Figure 190. Gypsum Rosette, "Desert Rose," Texas

to iron. Carbon is essential, also, in the smelting of the ores of iron and of many other metals. The longer we live the more we shall be impressed with the great importance of carbon and its compounds.

Its occurrence in the mineral kingdom introduces us to *diamond* and *graphite*, to the large group of the *carbonates* (page 27), and to the *hydrocarbons* (page 163), including *coal* and *petroleum*, which are by far the most valuable mineral products of our country.

Diamond is pure carbon, symbol C. As a cut gem, it is probably the best-known of all minerals, but very few people, comparatively speaking, are familiar with its appearance in the rough. It is with this that the mineral collector is especially interested. Who can tell whether the ability to recognize it in its natural state may not lead some student of this book to discover an important new source of supply. This did happen in the case of Sir Thomas Cullinan, at the time a day laborer, who learned the appearance of rough diamonds and of the minerals associated with them and then devoted his spare time to searching for them in South Africa. He was rewarded by discovering what eventually became the Premier Mine, which has produced $150,000,000's worth of diamonds, including the mammoth Cullinan diamond. The poor laborer became a multimillionaire and a member of the English nobility, while

the company organized to operate the mine paid to its stockholders every year nearly four times their original investment.

Forms: Diamond usually occurs in distinct isometric *crystals,* whose forms vary greatly, though the octahedron and the dodecahedron are the most common. Very often the crystals are rounded (figure 82),

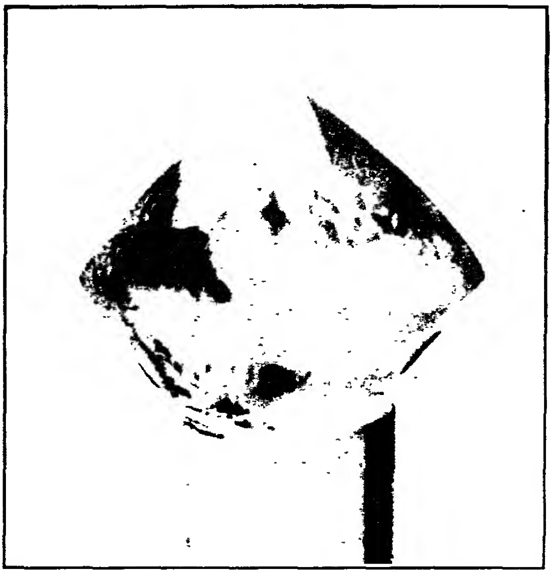


Figure 191. Diamond Crystal, 442 Carats, found 1917 Reported to be the Most Valuable Stone Found in the Mines at Kimberley, South Africa. Courtesy of DeBeers Consolidated Mines, Limited

frequently concealing the form and making it appear more complex than it really is. Little triangular depressions or elevations (figure 192) are often seen on the octahedral faces. Twins (figure 103) are abundant. Figure 191 is a photograph of a fine octahedron, weighing 442 carats found in 1917 in one of the Kimberley mines. Besides the usual crystallized forms, a black, *massive variety,* known as *"carbon"* or *"carbonado,"* occurs in Brazil, harder and tougher than the crystals.

Cleavage is octahedral and easily obtained, leaving very brilliant surfaces which it is easy to mistake for crystal faces.

Hardness is the distinguishing property of diamond, for it is much harder than any other substance. While *it is number 10 in the scale of hardness,* page 31, it is actually many times as hard as corundum, number 9.

Luster: Adamantine luster takes its name from the Greek name of diamond, *adamas, adamant.* Diamond shows this type of luster more perfectly than any other mineral (see page 107).

Color: The typical diamond is absolutely colorless, but light yellow is common, also brown. The percentage of stones of other colors is exceedingly small and usually the fancy-colored diamonds—blue, green, orange, pink or red—are quite small.

Other properties of diamond are summarized below in comparison with graphite.

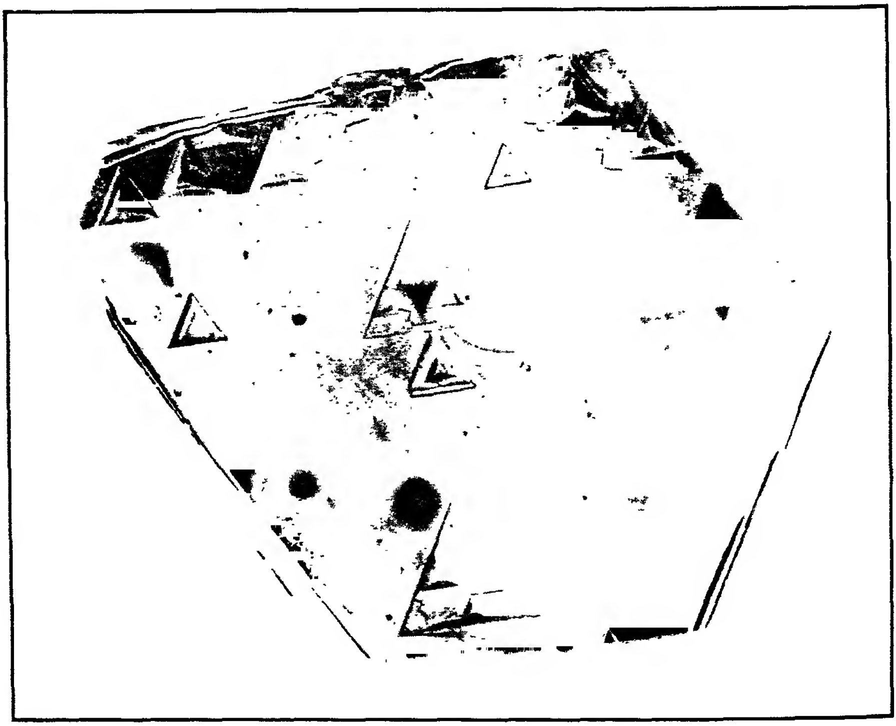


Figure 192. Diamond, Natural, Triangular Growth Projections on Face of Octahedron. Kimberley, South Africa

Diamond Gems: Diamond is much the most popular and important of all gems. This is due to its unequalled hardness, brilliancy and play of colors. Its wonderful *play of colors*, when cut into a gem, is explained on pages 110. 116. The maximum reflection of light from the inner surfaces of the lower facets is secured by grinding these facets at definite angles, thus greatly increasing the brilliancy. Colorless and water-clear gems are said to be of "first water," the highest grade being called "blue-white" by the jewelers. Contrary to the general belief, these are not the most expensive of gems, this honor being accorded to the fancy-colored stones noted above. These are, however, so rare as to be practically unknown to most people.

Historic Diamonds: While small stones constitute a very large percentage of the diamonds found, extra large stones are occasionally found. These are valued at much more than proportional prices, some of them having been sold for many hundreds of thousands of dollars. The *"Kohinoor"* has been known since 1304 and remained in the Orient until 1850 when it was sent to England. It is probably the most famous of the historic diamonds. The *"Orloff"* diamond is said to have formed one of the eyes of a Hindoo idol. It was stolen and was later sold to Prince Orloff of Russia for $450,000 and eventually was mounted in the imperial scepter. These two stones, also the *"Great Mogul,"* which is said to have weighed in the rough nearly 800 carats, and the magnificent, deep-blue *"Hope"* as well as many other famous diamonds, came from India.

The South African fields have produced many huge diamonds including the *"Cullinan,"* the largest in the world, which weighed in the rough 3,106 carats, or over one and a third pounds. It was presented to King Edward VII and was then cut into over a hundred stones, two of which are larger than any others known. These may now be seen among the crown jewels in the Tower of London. Among many other South African diamonds of note are the *"Jubilee,"* the *"Victoria"* and the *"Tiffany."* The last named is an exceptionally beautiful, yellow stone which has been displayed at many international expositions, in-

Figure 193. Diamond Crystal in Conglomerate; Namaqualand, South Africa

cluding Chicago, 1933. Thirty diamonds weighing over 400 carats were recorded from South Africa up to 1932.

Occurrence: The earliest, authentic finds of diamonds were in India, which for many centuries was practically the only source of supply. The diamonds were recovered by washing loose gravels, or from conglomerate or sandstone rocks. As many as 60,000 men are said to have been employed at the famous diamond mines near Golconda, India in 1665. These have now been abandoned, but there is still considerable mining near Allahabad, India.

About 1729 diamonds were discovered in the gravels and conglomerates of Brazil and that country has been an important producer ever since.

The great diamond mines of the world are those in South Africa which are working in the rock, kimberlite (page 257), or, as it is known locally, "blue ground." Great "pipes" occur, filled with this curious mixture of minerals which has been forced up from thousands of feet below the surface by the pressure of confined gasses. The diamonds are scattered through this rock very sparingly and irregularly. How they got there has long provoked controversy among geologists.* Some idea of the very small quantity of diamond in the kimberlite may be secured by noting that in 1926 the production of one of the largest and richest mines averaged but one carat from 5378 pounds; or, to put it another way, there would be about one chance in 3585 of finding a carat of diamond in a specimen of kimberlite 3x4 inches in size, weighing a pound and a half.

It was in 1867 that some children playing in the river gravel found the first South African diamond. Some three years later diamond was found in kimberlite at Jagersfontein and within another year four other great mines were discovered, all in the vicinity of Kimberley. Others were found in other parts of South Africa during the next few years, but for twenty-one years after their discovery the "big five" were the only profitable mines. Then another great mine was found and, finally, in 1902, the greatest of all, the "Premier (Transvaal)" mine, figure 194, was discovered. Since that time no large diamond mine has been discovered anywhere. The mineral is, however, widely distributed all over the world, and were it not for the tremendous production of the South African mines and the control exercised over their production, some of the occurrences might be regarded as important.

The richest occurrence in the United States is in Arkansas, where rock similar to the South African is found. At least ten thousand

* See "The Genesis of the Diamond," by A. F. Williams, 1932, a marvelously interesting book, in two sumptuous volumes magnificently illustrated

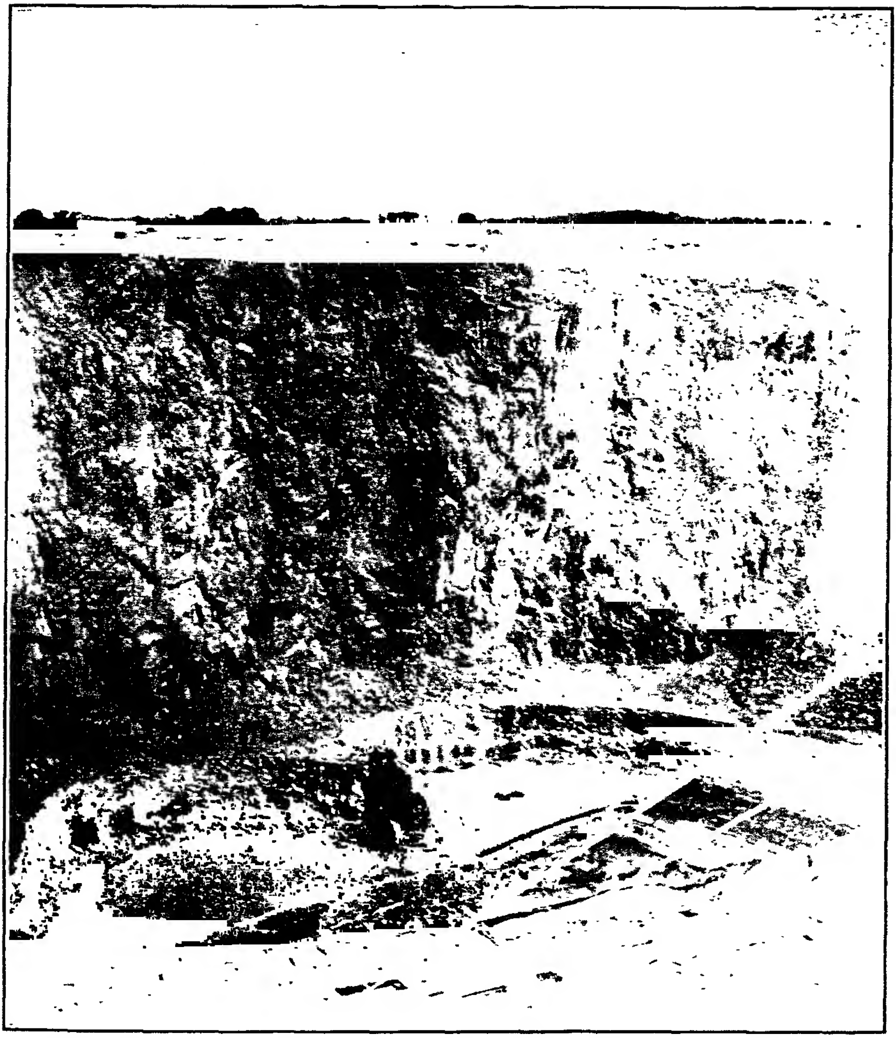


Figure 194. Premier Diamond Mine, Transvaal, South Africa, on April 19, 1928. (G. L. English Photo)

diamonds have been recovered there, the largest weighing twenty-one carats. Some of the best may be seen in the United States National Museum.

Uses: While the chief use of diamond is as a gem, as noted above, its industrial uses are of far greater practical importance. The extra-hard, black variety, "carbon," mounted in "diamond drills," has made it possible to drill through solid rock to a depth of over ten thousand feet, and preserve the core. The much more common "bort," which is diamond too inferior to be cut into gems, has large uses for sawing,

grinding and polishing. Minute diamonds are mounted for glaziers' use and perforated diamonds are used as dies through which fine tungsten wire is drawn for electric light filaments.

Graphite, "black lead," is pure carbon, symbol C. It is a mineral we use every day, for, mixed with a little clay as a binder and then compressed, it forms the "lead" of our lead pencils. Other uses are mentioned below. Its applications in the arts are due chiefly to its softness, the flaky structure of the crystalline variety, its infusibility and its resistance to acids. Its properties are noted below.

Graphite and molybdenite much resemble each other. Both are so soft as to mark paper, but can be readily distinguished by their respective colors, black and bluish lead-gray. Graphite is a mineral with which every beginner should become familiar, yet it is quite possible that he may not meet it in the field. Specimens should, therefore, be purchased. There are comparatively few localities which yield it in commercial quantities, but it is widely distributed in little scales in many rocks, as in mica-schist, and the marble of Ticonderoga, New York. It forms the odd "crow's feet" in the Tennessee "marble."

Diamond and graphite are both pure carbon, yet no other two minerals of the same composition differ so greatly from each other. Let us compare them.

Diamond and Graphite Compared

Properties	DIAMOND	GRAPHITE
Crystal form	Isometric	Hexagonal
Other types	Spherical; massive	Grains, scales, massive, foliated, columnar
Cleavage	Octahedral, perfect	Basal, perfect
Tenacity	Brittle	Flexible
Hardness	10	1 to 2
Specific gravity	3.52	2.20
Luster	Adamantine, greasy	Metallic; dull when massive
Color	Colorless, yellow, brown; rarely green, pink, orange, red, blue; black when massive	Iron-black to steel-gray
Transparency	Transparent or translucent; opaque when massive	Opaque
Conductivity	A non-conductor of electricity	A conductor of electricity
Combustibility	Combustible	Non-combustible
Composition	Pure carbon	Pure carbon
Usually occurs in	Kimberlite, conglomerate, deposits of gravel	Granite, gneiss, mica schist, crystalline limestone
Chief localities	South Africa, Brazil, India	Madagascar, Bohemia, Ceylon
Chief uses	As a precious stone; an abrasive, in wire drawing	In lubricants, paints, stove polish, crucibles, lead pencils, foundry facings and other refractory products

The Hydrocarbons

It is beyond the scope of this book to treat in detail of such highly complex substances as the natural compounds of carbon with hydrogen, or with both hydrogen and oxygen. In most cases they are not true minerals, because they lack a uniform chemical composition. Nevertheless, the supreme economic importance of some of the members of this group justifies their mention and the earnest student, seeking a livelihood from the mineral kingdom, may find it highly desirable to become thoroughly familiar with some of them, while everyone should know a little about them.

Ozocerite, "mineral wax," is the simplest of the natural hydrocarbons worthy of our attention. It is rather sticky and slightly lighter than water. Its color is commonly brown to black and it often has a foliated structure. It is mined in considerable quantities in Galicia and formerly in Southern Utah. It is used in making the best grade of candles and electrotype wax, while a derivative, "ceresine," is used for bottles for holding hydrofluoric acid.

Amber is the most attractive of the natural hydrocarbons. When pure it is transparent and of a beautiful, deep honey-yellow color, or occasionally brownish-red. It is often cloudy and nearly or quite opaque and white. Its hardness is 2 to 2.5 and it is slightly heavier than water. Its luster is resinous and it has a conchoidal fracture. One interesting characteristic, possessed also by copalite, is that it is negatively electrified by friction, preferably with a silk handkerchief, so that tiny bits of paper will be picked up. This fact was known to the ancients, who called amber "*electrum*" and our word electricity traces its origin to this source. By far the most important locality is the Southern coast of the Baltic Sea. Here it is extensively collected and manufactured into various commercial objects, such as beads, and cigar holders. A large, government-owned factory is located at Königsberg in East Prussia. Amber is a fossil resin and during its formation it frequently entrapped insects which have been preserved to this day.

Copalite is a fossil resin, very similar in appearance to amber It is imported into the United States in considerable quantities from New Zealand, where it is known as "Kauri Gum," also from Africa, Manila and other far-away places. It is chiefly used in the manufacture of linoleum and also fine varnishes and cellulose lacquers.

Petroleum is a mineral product of which the United States in 1929 produced over a billion barrels. It is known everywhere as "oil" and

the romance of oil is as fascinating reading as any novel. Petroleum is far from being a simple mineral, being composed chiefly of three substances, paraffin, benzene and naphthalene, though in California asphaltum is an important constituent. The commercial use of petroleum is a development dating back scarcely more than a hundred years. but it was not until about the beginning of the twentieth century that the invention of the internal combustion engine, burning gasoline, which is a petroleum product, created a demand for petroleum far exceeding any previously existing. The number and variety of petroleum derivatives are almost unbelievable, including gasoline, naphtha, benzine, kerosene, paraffin, lubricating and fuel oils. The appearance of crude petroleum varies greatly in different localities, but most commonly it is a dark brown, or greenish, sticky oil, light enough to float on water. The chief producing wells at present are in Texas, California, figure 195, and

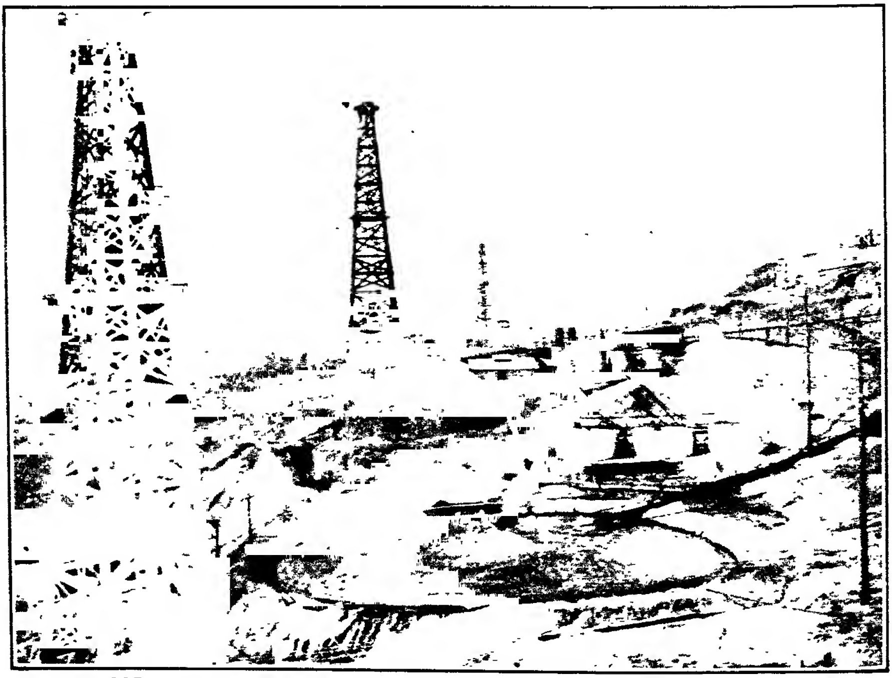


Figure 195 Oil Wells and Storage Tanks, Baldwin Hills, Los Angeles, California. (G. L. English Photo)

Oklahoma. Many foreign countries contribute large quantities to the output.

Asphaltum was probably formed from petroleum. It varies greatly in appearance, sometimes being a brown or black solid, occasionally with

a high luster as in that from Venezuela, or again dull as in that from California. From such solid forms it grades off to semi-liquid and liquid states, thus passing into petroleum. It always has a characteristic bituminous odor, which is familiar to everyone who has passed a group of workmen laying an asphalt street pavement, which is its most important use. The famous Trinidad Lake is a pool of asphaltum, liquid and hot in the center and passing through intermediate stages to a cold, solid rock on the border.

Wurtzilite is a brilliant, black solid, which breaks with a conchoidal fracture. It much resembles *uintahite* (*gilsonite*) figure 196, which is

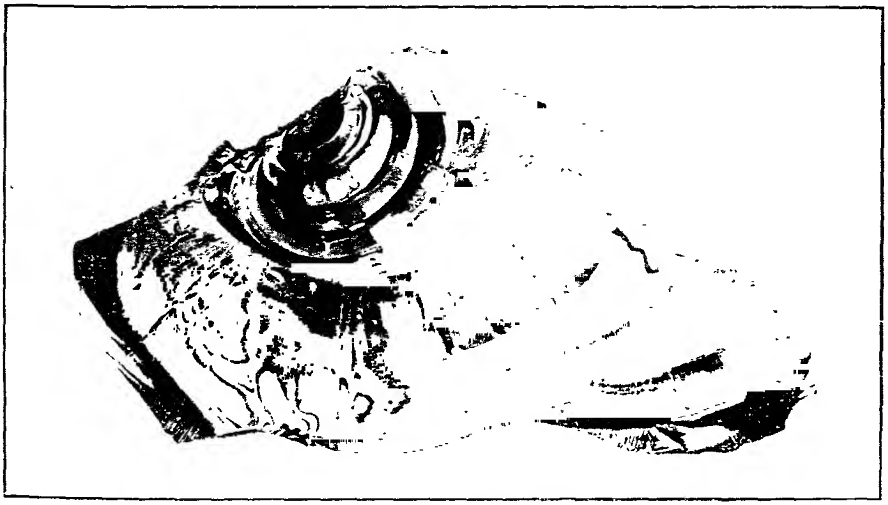


Figure 196. Uintahite (Gilsonite), Utah, Showing Its Conchoidal Fracture

found near by in Utah, but is readily distinguished from it by its sectility, (page 36). It may be shaved with a knife, into thin, curled shavings, but the process ends when, all of a sudden, they snap and break off. Wurtzilite is used for roofing under the name of "elaterite."

Mineral coal shares with petroleum the honor of being the most valuable of all the mineral products of the United States. In the year 1931 it added over $1,000,000,000 to the nation's wealth. Coal was formed by the change, during the geological ages, of vegetable matter, the transition being from peat, through lignite to anthracite. There are many varieties, differing markedly from each other in appearance and usefulness.

Those who live near to the great mines of *anthracite* in Pennsylvania doubtless think of this variety as the most important of fuels, but its

value is less than half that of bituminous coal. It is comparatively hard, highly lustrous and ignites less readily than other kinds of coal.

Bituminous coal, which also occurs plentifully in Pennsylvania, is abundant in many other states. It is commonly known as "soft coal." It crumbles easily and is much dirtier and burns with a much greater amount of smoke than anthracite.

Cannel coal is a compact variety of bituminous coal having a conchoidal fracture and little, if any, luster. It is in favor for burning in fireplaces.

Lignite is another, more variable, variety of bituminous coal, sometimes retaining the form of the wood from which it is derived. Ordinarily it has a brown color and is, therefore, called *brown coal.*

Jet, strange as it may seem, is a "jet black" variety of brown coal! It is very compact and takes a high polish. It was formerly used for mourning jewelry.

The economic importance of coal can scarcely be estimated. The United States produces nearly half of the world's output. An average of nearly 2,000,000 tons per day is mined and it constitutes nearly a third of all the freight carried by the railways. Notwithstanding the enormous quantity mined, it is estimated that there is enough coal in this country to last for a thousand years! The romance of coal is even greater than that of petroleum. It has been said that two pounds of coal, properly utilized, will do the work of a man for a day, which is equivalent to hiring a man for one cent a day! What marvellous transformations have resulted from the conversion of coal into electricity, and into coke, with its enormously valuable by-products, chiefly gas, ammonia, light oils, tar and its many derivatives. Greater discoveries yet await those who seriously study coal and other hydrocarbons and their chemistry. A fortune may be waiting for you right here.

CHROMIUM MINERALS

Metallic Chromium does not occur in nature, but it is well known through its use in stainless steel, an alloy of chromium and iron. It is a brilliant, silvery-white metal, of exceptional hardness, and its uses are rapidly increasing. Its only plentiful ore is the mineral chromite.

Chromite, an oxide of iron and chromium, $FeO.Cr_2O_3$, is a mineral of great commercial importance, though the beginner will not find it especially attractive, as it ordinarily occurs in iron-black masses with submetallic *luster.* The resemblance to massive magnetite is often quite strong, but it can usually be readily distinguished by the fact that it is but *very slightly magnetic* and has a brown *streak,* while magnetite has

a black streak. Care must be exercised, however, not to confuse it with franklinite, which also has a brown streak. The difference in their luster will be an aid, while chromite almost always occurs in serpentine or chrysolite. If either of these is noticed adhering to the mineral, it is reasonable to assume that it is not franklinite and if the streak is brown, that it is not magnetite, which is sometimes associated with serpentine. Such sight tests will sometimes lead the beginner astray as he will find that they are not absolutely reliable in all cases, and as he advances in his study of mineralogy he will appreciate the importance of supplementary chemical tests which will settle the identity of his specimens beyond a doubt.

Hardness: 5.5. *Specific gravity:* about 4.5. *Tenacity:* brittle.

Form: isometric; though it occurs but rarely in crystals, these being small octahedrons; usually in fine-granular masses.

Ocurrence: The world's greatest deposits, in Southern Rhodesia, are now the chief commercial source of supply. Much chromite is also mined in India, New Caledonia, and other countries. The United States produces very little. "Black Sands" which abound in many regions, often contain chromite, sometimes in minute octahedrons.

Uses: Because it is fused with great difficulty, chromite is used in the manufacture of refractory bricks for lining open-hearth furnaces. It is the material from which "ferrochrome" is made. This is an alloy of chromium and iron. When added to special steels it gives them great strength, thus adapting them for use in making safes, armor plates, projectiles, and high-speed tools. A large majority of the "alloy steels" contain chromium. Chromite is also the source of the many chromium salts of beautiful red, yellow and green colors, which are used as pigments, in coloring pottery, painting, printing wall papers and also in dyeing and calico printing. Chromium compounds have many other uses.

Other Chromium Minerals. Crocoite, lead chromate, $PbCrO_4$, occurs in monoclinic, elongated-prismatic crystals of a gorgeous red color in Tasmania, and less plentifully in the Ural Mountains and Brazil. It is too rare to be of commercial importance, but yields some of the most magnificent of all mineral specimens and adds greatly to the attractiveness of any collection of which it is a part.

The presence of small percentages of chromium in several minerals causes remarkable color changes, thus emerald, uvarovite, and fuchsite, are chromium-bearing varieties respectively of beryl, garnet and muscovite and all of them have a rich emerald-green color.

COBALT MINERALS

The metal Cobalt is closely associated with Nickel in its nature and properties. It is found chiefly in the minerals *smaltite* and *cobaltite.* Study of cobalt minerals is beyond the scope of this book.

COPPER MINERALS

Copper, the metal of the poor. Everyone knows that copper is a red metal, for who has not admired the "bright penny" of England or the "bright cent" of the United States? Our cent contains 95% of copper, with 4% of tin added to give it greater hardness and 1% of lead.

Next to iron, more copper is used than any other metal. There must be reasons. Can you tell what they are? Its chief use is as wire in the electrical industries. That points to its *ductility*, mentioned on page 36 and to its excellence as a *conductor of electricity.* The statement has been made that there are probably 100,000,000 miles of copper wire in use in the United States Its use as sheet copper in roofing demonstrates its *malleability.* Copper enters into everyday life in a great many ways. You will find it worth while to list those with which you are familiar and you will then better understand why the production of copper has increased so marvellously. Our own country in 1851 produced only about 1,000 tons, while in 1926 the yield of our mines was 869,811 tons.

Native Copper, the only metal found abundantly in nature, occurs along the South shore of Lake Superior in some of the greatest mines in the whole world, over 6,000 feet deep. They have been worked for over four hundred years. Copper has been known and used from the earliest times, indeed the "copper age" followed the "stone age." The Romans called the metal cuprum, and from this name the chemical symbol of the element, Cu, is derived. A mass weighing about 420 tons was found in 1857, but the chief ore of the Lake Superior region is low grade, the copper forming the cementing material of pebbles which make up a conglomerate. This region is famous for the wonderful groups of copper crystals, figure 197, which it produces and for the marvellously beautiful specimens of limpid calcite crystals with enclosures of bright red copper. The finest of these are among the most spectacular mineral specimens in the world. It crystallizes in the isometric system, the *crystals* often being highly complex. Its *hardness* is 2.5 to 3.; *specific gravity:* about 8.85.

The Copper Minerals. The chief ores of copper, besides the native metal, are chalcopyrite and chalcocite, but there are others which are

abundant in certain regions, among which are bornite, cuprite, malachite, azurite, chrysocolla. Besides these there are many rarer copper minerals, including tetrahedrite and also some of the most beautiful of minerals; for the copper minerals, almost without exception, are brightly colored, many of them being of rich blue or green colors, of shades not known in any other minerals. Minute crystals of these are a great delight to the microscopist.

Figure 197. Copper Crystals, Houghton County, Lake Superior, Michigan

Chalcopyrite, popularly known as copper pyrites, is a sulphide of copper and iron, $CuFeS_2$, containing 34.5% of copper. It is a very widely distributed mineral in many rocks. It has a beautiful brass-yellow *color,* sometimes pale because of the admixture of pyrite, and often *tarnished* much darker and showing charming rainbow colors.

It is decidedly softer than pyrite, which it frequently resembles, and from which it can be easily distinguished by testing its *hardness,* which is 3.5 to 4., so that it can be readily scratched with a knife.

It much resembles gold, and, like pyrite is called "fool's gold," but it is distinguished readily if a bit of it is pounded, when its greenish-black streak is seen and also its *brittleness,* while gold is always malleable.

Its *specific gravity* is about 4.2, while gold is 19.33, nearly five times as heavy! That does not, however, aid the beginner much in distinguishing between the two minerals in the field, for he is not likely to find a piece of pure gold large enough to enable him to compare it with the chalcopyrite. It would be a fair assumption to make, however, that if he did find a large piece it almost certainly was not gold, and was chalcopyrite; then the hardness test would settle the question as to its being pyrite or chalcopyrite.

Its *crystals,* figures 41 and 198, which belong to the tetragonal system, are comparatively rare and often complex. Read about them again on page 47. Very fine groups of crystals come from Japan, but while there are but few outstanding localities for crystallized specimens, a great many copper mines produce the massive mineral in large quantities.

Figure 198. Chalcopyrite Crystals (Sphenoids) on Dolomite, near Joplin, Missouri

Bornite, is another sulphide of copper and iron, Cu_5FeS_4. It contains 55.5% copper, much more than chalcopyrite. It is very much rarer, though in some mines it is abundant enough to constitute an important ore. Secure a specimen of it and break it. You will be amazed to find that on a fresh fracture it has the peculiar reddish-brown *color* of pinchbeck metal. This quickly *tarnishes* to a beautiful blue. No other mineral is like bornite in this respect. It may be further distinguished by its grayish-black *streak*, and its *hardness* of 3. *Specific gravity* is 4.9 to 5.4. Massive specimens are very beautiful, but the exceedingly rare *isometric crystals* are dull and lack the characteristic blue *tarnish*. Very fine, pure masses, come from Messina in the Transvaal: Bisbee, Arizona and a few other localities.

Chalcocite, often called copper glance, is a pure copper sulphide, Cu_2S, containing 79.8% copper. It has a dark lead-gray *color*. It usually occurs *massive* and when pure it is apt to be *fine-granular* and

show an imperfect conchoidal *fracture.* Its *hardness* is 2.5 to 3 and *specific gravity:* about 5.7. It is the most important of the copper ores and occurs in vast quantities in the mines at Butte, Montana, and also in Arizona and many other regions. *Crystals* are very rare and are of complex orthorhombic forms.

Cuprite, sometimes called "ruby copper," or red copper ore, is an oxide of copper, Cu_2O. It is the only one of the copper minerals, except native copper, which has a *red color.* It sometimes much resembles cinnabar, from which it may be quickly distinguished by its brownish-red *streak,* while cinnabar (and proustite) have a scarlet streak. Its superficial color varies considerably, from crimson to cochineal-red, but it grows darker on exposure to light and becomes almost black. Its *hardness* is 3.5 to 4, and *specific gravity:* about 6.

Its *crystals* are usually small cubes, octahedrons, and dodecahedrons and combinations of these forms, but its most wonderful occurrence, the variety chalcotrichite, is in cubes so greatly elongated in one direction that they form capillary crystals (see page 59). These are gloriously beautiful under the microscope. It is fairly abundant in the upper levels of copper mines. At Chessy, France, crystals of cuprite occur superficially changed to malachite.

Tetrahedrite, often called "gray copper" especially by miners, is a compound of copper, antimony and sulphur, $Cu_8Sb_2S_7$. It is a rich ore containing 52% of copper. It often contains silver as an impurity, sometimes as much as 30%, and is then far more valuable as a silver ore. Its *color* is quite characteristic, being "between flint-gray and iron-black." Its *streak* is like its color, and its *luster* is metallic, a little dull in masses, but often exceedingly brilliant in *crystals.* These, as indicated by its name, are of tetrahedral form, often highly complex. Tetrahedrons are half forms of octahedrons, that is they have octahedral faces but only half as many as the octahedron. *Hardness* varies between 3. and 4.5, and *specific gravity* ranges from 4.4 to 5.1. Bolivia produces the finest specimens of tetrahedrite, and excellent groups of crystals also come from England, Transylvania and a good many other localities. The massive ore is fairly abundant in copper and silver mines.

Azurite and Malachite. These two minerals both crystallize in the *monoclinic* system and have a *hardness* of 3.5 to 4. They are both important ores of copper and each is a copper carbonate combined with water, but here their similarity ends and it is interesting to note how a slight change in the percentage of the water, from 5.2 per cent in

azurite to 8.2 per cent in malachite, produces another mineral with radically different characteristics. Both of these minerals result from the action of carbon dioxide, dissolved in water or present in the air, upon native copper, cuprite, or some other copper mineral, near the surface of the ground. Azurite is first formed and then it is gradually changed to malachite. Specimens which show only a partial change are frequently seen, especially at Tsumeb, South West Africa, where large crystals of azurite show its characteristic blue color outside, while within is the green color of the malachite. When the change is complete such a specimen is called *malachite pseudomorph after azurite.* Bisbee, Arizona and Tsumeb both produce very fine specimens of this instructive occurrence. Masses composed of the two minerals are sometimes found which take a high polish and, because of the pleasing contrasts of color, make most beautiful specimens.

Azurite is sometimes called *blue carbonate of copper*, but, as we have just seen, water is chemically combined, yielding the formula, $2CuCO_3.Cu(OH)_2$.

Hardness: 3.5 to 4; *specific gravity:* 3.77 to 3.89.

Its blue *color* is very characteristic, the only other mineral which closely resembles it being the rare sulphate of lead and copper, linarite The color varies much, however, from a light blue to almost black.

Crystals abound in certain localities, notably at Tsumeb, at Chessy in France, and Bisbee, Arizona, and the best of them are among the most magnificent of all mineral specimens. The forms are usually exceedingly complex. Earthy forms and masses of drusy crystals are common. The *luster* of the crystals is vitreous, changing to dull in the earthy form.

Malachite, often called *green carbonate of copper*, though, as noted above, water is chemically combined, has the formula, $CuCO_3.Cu(OH)_2$. Its most characteristic color is a rich green.

Hardness: 3.5 to 4.; *specific gravity:* 3.9 to 4.03.

Distinctly formed crystals are rarely seen, though radiating tufts are not uncommon. The usual *form* is mammillary, figure 120, the masses showing a banded and compact-fibrous *structure*. Such material is susceptible of a high polish. Superb specimens have been found at Bisbee, Arizona, with velvety surfaces, one of which, in the American Museum of Natural History, is shown in figure 199.

Russian malachite is highly prized and has been manufactured into vases, table tops and other art objects, and even used for pillars in some European churches. Belgian Congo, and Northern Rhodesia are now the largest producers.

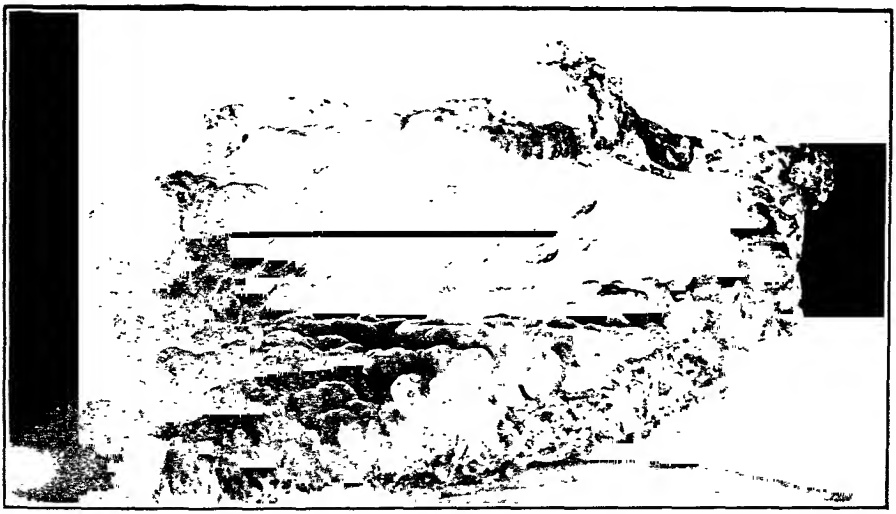


Figure 199. Velvet Malachite, Bisbee, Arizona, in American Museum of Natural History

Chrysocolla is a silicate of copper, with water, $CuSiO_3.2H_2O$. It usually has a beautiful sky-blue or bluish-green color. It is *massive*, or sometimes botryoidal and very brittle. Its *hardness* varies from 2 to 4. Its *specific gravity* is only a little over 2. It is fairly abundant in the upper levels of copper mines as in Arizona and other Western States.

Dioptase is another copper silicate, $CuSiO_3.H_2O$, formerly regarded as a very rare mineral, but recently found in Africa in sufficient quantities to be mined as a copper ore. It is one of the most beautiful of all minerals, its rich, emerald-green color lighting up any collection. Groups of its crystals from Russia were formerly so rare as to be distinguishing marks of the highest grade of mineral collections; now they are seen in many collections of lesser rank. It has a *hardness* of 5, and *specific gravity* of about 3.3.

Other Copper Minerals. There are scores of other copper minerals, nearly all of which are very rare, including arsenates, phosphates, vanadates, nitrates, sulphates. These present one of the most delightful fields for study after the rudiments of mineralogy are learned.

GOLD MINERALS

Gold, the King of the Metals. From earliest days gold has been the most sought of all the metals. Its use for coins, watches, jewelry and in many ways in the arts, is so well known as to need no emphasis. Until 1933 the value of gold in the United States, was fixed by law at $20.67

per ounce Troy. A much higher value has since been placed upon it, and its use has been limited.

Native Gold, symbol Au (from its Latin name, aurum), is highly prized by collectors, especially when crystallized.

Its *crystals* belong to the isometric system. Octahedrons and dodecahedrons are the most common forms, and they are often much distorted and skeletonized, and the faces frequently show little triangular elevations.

Gold occurs in igneous, sedimentary and metamorphic rocks all over the world. A list of even its important occurrences would be a very long one. Probably it is most frequently found in quartz veins, though the greatest deposit of gold in the world, that of the Witwatersrand (often called "The Rand"), in the Transvaal, South Africa, is in quartz-conglomerate. In the early days, gold mining was chiefly in the gravels and sands of stream beds and the adjoining hillsides, known as "placer deposits." These were at first washed in a primitive manner to remove the lighter ingredients, leaving the gold behind; in later years great dredges, operated by steam or electricity, have largely replaced the small miner; or powerful streams of water have been directed on the gravels washing them down into sluices where the gold is separated. This method is called hydraulic mining. Gold occurs in the rocks chiefly as stringers, thin leaves or plates, figure 200, and scattered masses. As the rocks disintegrate these are released and washed down

Figure 200. Gold, Redridge Mine, Nevada County, California. The Arm, of Nearly Pure Gold, is 14½ Inches Long and is Attached to a Mass of Quartz. The Specimen is Estimated to Contain 36 to 40 Ounces of Gold

into the streams and valleys where by rubbing against harder particles they become broken and rounded into grains, fine dust or flat scales. If the original mass was large, the placer gold may be in large, rounded masses called "nuggets." The largest nugget ever found was the famous "Welcome Nugget" found in 1858, in Australia, which weighed over 150 pounds and was valued at $41,883. It measured 20 by 9 inches.

The *hardness* of gold is only 2.5 to 3, which readily distinguishes it from pyrite, whose hardness is over 6.

Its *specific gravity,* when pure, is over 19, but unless a large mass of it is available for comparison with other minerals its great weight is not a convenient test.

Its *color* is typical golden-yellow, but, because silver is almost always alloyed with it, sometimes as much as a third of the "gold" being silver, as in the variey known as *electrum,* the color is ordinarily much lighter. Chalcopyrite often greatly resembles gold in color, and as its hardness is not very much greater than that of gold, it is sometimes difficult to tell them apart. One test, however, will quickly settle the question. Gold is highly *malleable* (see page 35) and chalcopyrite is brittle; therefore, if a small fragment of the mineral breaks readily it cannot be gold, for gold simply flattens out. The test will also show the streak of chalcopyrite to be greenish-yellow, while if gold is drawn across a streak plate it will be seen to have a *streak* the same as its external color. If it is borne in mind that gold is the only yellow mineral which is malleable, there will be no difficulty in identifying it whenever a piece can be tested large enough to show the malleability.

Other sources of gold: Considerable gold is recovered from pyrite, in which it occurs as an impurity; also, in much smaller quantities from arsenopyrite and pyrrhotite. The only known compounds of gold found in nature are with the rare element, tellurium, the best known of these being the tellurides, *sylvanite* and *calaverite,* found chiefly in Colorado and Western Australia.

The romance of gold is a fascinating subject about which to read, while a collection of the many kinds of gold will afford much pleasure.

HYDROGEN MINERALS

Hydrogen constitutes about one per cent of the earth's crust. It is an essential part of a great many minerals, and is also present in the great group of hydrocarbons (see page 163), and in various natural gases. One of its compounds, water, is universally distributed.

Water, hydrogen oxide, H_2O, is a liquid between zero and 100° centigrade; below zero, it is a solid, either *ice* or *snow;* above 100° it is

a vapor, *steam;* but at all ordinary temperatures *water vapor* is present in the air.

Pure water, either liquid or as ice, is *colorless* and *transparent* except in large quantities, when it shows a beautiful "sea-green" color.

Its *specific gravity* is 1, it being the standard of comparison for all minerals. Ice has a specific gravity of 0.91, and consequently floats on water.

Form: Ice crystals result from the freezing (solidifying) of water (see page 83); snow crystals result from the freezing of water vapor. Both of these forms are hexagonal in crystallization. Snow crystals occur in a greater variety of forms than any other mineral. They have been photographed with wonderful skill by the late Walter A. Bentley, a few of whose thousands of illustrations are reproduced on page 57.

Uses: More water is used than any other mineral, its contribution to life being too well known to need comment. It may not be realized, however, that water is the most important agency in the weathering and destruction of the rocks, because it dissolves so many minerals and also because of the enormous pressure which it exerts in freezing, due to its expansion. This amounts to about 276,000 pounds per square foot. If water fills an open crack in a rock and then freezes, it is very apt to tear the rock apart. This action is strikingly shown along ocean-side cliffs in the spring, when great masses of rock, detached by the power exerted by freezing water, fall to the lower ground. It would be most interesting to list every use of water in its several forms. Such a list would be far too long to include in this little book.

Water is a good illustration of how the average person takes common things for granted, never noticing their beauty. How marvelously beautiful are the snowflakes, the great fields of snow, the glaciers, the icebergs, the snow-covered mountains, the great open stretches of ocean, lakes and rivers, the magnificent water falls! Surely water is a thrilling mineral!

IRON MINERALS

The chief reason for the small supply of native iron is the fact that iron "rusts" very easily, which is only the popular way of saying that it readily combines with oxygen. The result is that the ores of the great iron mines of the world are largely oxides of iron, the particular minerals being *hematite, limonite, magnetite.*

Evidences of the presence of iron are to be seen all over the world. The "red clay" of the great Piedmont plateau in the Eastern United States owes its color to iron oxide. The marvellously beautiful colors of the rocks in the Grand Canyon, Zion Park, and Yellowstone Park are largely due to oxides of iron. Iron too adds the showy colors to building

bricks, to the chlorophyll which gives the trees and plants their lovely green colors, and in countless other ways it contributes to the beauty of the world. Metallic iron enters into our daily lives in ways too numerous to mention, but many of which are known to us all, while other uses in laboratories and factories contribute, though unseen to the people, to our essential needs as well as to our comforts.

Iron has been known from antiquity, but only during the last two hundred years, since coal has been employed to reduce its ores. has it been manufactured on a large scale. Steel production has also grown enormously, while phenomenal progress is being made today in adapting it to manifold uses by alloying it with small quantities of other elements, such as manganese, chromium, nickel, vanadium, tungsten, molybdenum. The romance of steel is one of the most thrilling pages in history and every cultured person needs to know something about this great outcome of the mineral industry.

Over 250 mineral species contain iron as an essential part of their composition, but only very few of these minerals are at all common and these alone are worthy of the beginner's attention. Those which will be treated here are: *native iron, pyrrhotite, pyrite, marcasite, hematite, magnetite, goethite, limonite, siderite.*

Native iron. It is remarkable that, while iron is the most used of all metals, native iron is a very rare mineral. It is found in very few places, the most notable being in Greenland. Many meteorites, figure 201, have fallen to the earth, but the aggregate amount of iron they have added to its stores is negligible.

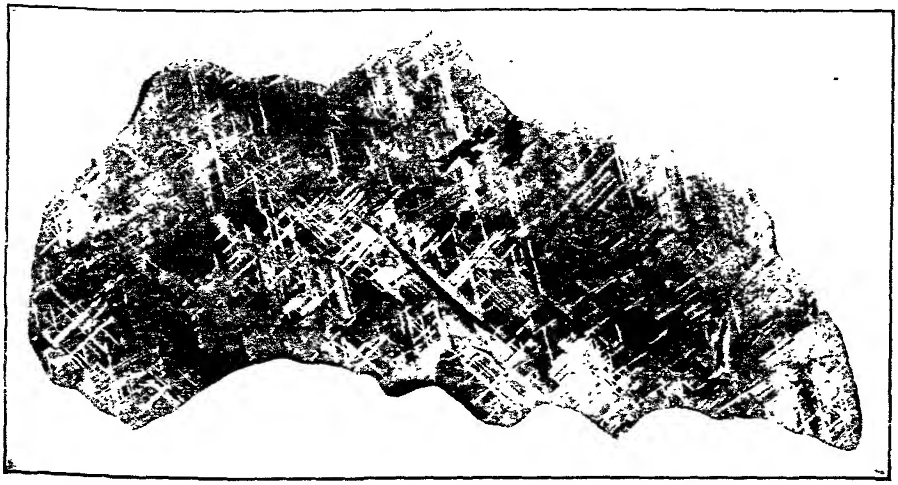


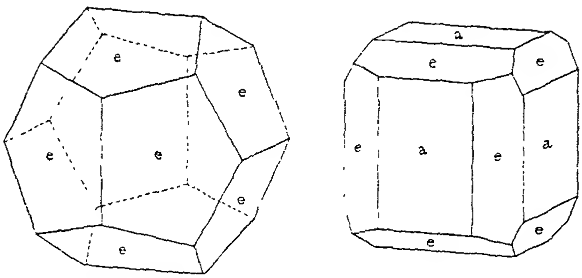
Figure 201. Section of Iron Meteorite, Mungindi, New South Wales. Polished and Etched to Show Crystallization

Pyrite, "iron pyrites," "fool's gold," is an iron sulphide, FeS_2.

Hardness: 6. to 6.5. *Specific gravity:* about 5.0. *Tenacity:* brittle. *Fracture:* conchoidal to uneven.

Color: pale brass-yellow. *Tarnish:* brown, but sometimes beautifully iridescent. *Streak:* greenish-black. *Luster:* metallic, brilliant. *Opaque.*

Form: Isometric crystals occur in many forms and combinations, such as cubes, often striated (see figure 89), octahedrons, pyritohedrons (figures 34, 202, 203). Many rare crystal faces are found on pyrite crystals. It is frequently massive or granular, occasionally fibrous.



Figures 202, 203. Common Forms of Pyrite Crystals

Distinguished from both chalcopyrite and gold by its greater *hardness.*

Occurrence: Pyrite is the commonest and most widely distributed of all the many sulphides. It occurs in vast beds, as at Rio Tinto, Spain, or as one of the constituents of ore veins, often associated with chalcopyrite, galena, sphalerite, hematite, siderite, quartz and many other minerals. It would require much space to mention even the most notable occurrences. Among the best American specimen localities are Leadville and Gilpin County, Colorado; Bingham Canyon, Utah; French Creek Mines, Pennsylvania. Brosso and Traversella, Italy, and the iron mines of the Island of Elba have produced many superb specimens.

Alteration: Pyrite is often found more or less completely altered to limonite, not infrequently hundreds of the altered crystals occurring loose in the soil. The form of the pyrite crystals, figure 134, is usually well preserved.

Uses: Pyrite has been mined in large quantities, not as an iron ore, but for the manufacture of sulphuric acid, but its use is declining. In the early days of the radio, it was largely used for radio detectors. It is sometimes a valuable ore of gold.

Marcasite, "white iron pyrites," "mundic," has the same composition as pyrite, FeS_2, but its *crystals* are orthorhombic.

Hardness: 6. to 6.5. *Specific gravity:* about 4.87. *Tenacity:* brittle. *Luster:* metallic.

Color: pale brass-yellow, whiter than pyrite, but often with a darker *tarnish.*

Streak: grayish, or brownish-black. *Opaque.*

Form: common in tabular, orthorhombic crystals, often twinned, frequently assuming spear shapes, whence the name "spear pyrites," or resembling a cockscomb and then called "cockscomb pyrites." Also common in nodules, radiated discs, stalactites, and other forms.

Distinguished with difficulty from pyrite when massive; good crystals are very different. It is somewhat whiter and much more liable to decompose. Powdered pyrite is completely dissolved in an equal quantity of strong nitric acid, while a residue of sulphur is left when marcasite is similarly treated.

Occurrence: It abounds in the chalk beds of Dover, England, in nodules; in fine, twinned crystallizations in Bohemia; in cockscomb and other forms in the Joplin region of Missouri-Oklahoma.

Pyrrhotite, "magnetic pyrites," iron sulphide, possibly $Fe_{11}S_{12}$. It is of no value as an ore of iron, but is a common mineral.

Hardness: 3.5 to 4.5. *Specific gravity:* about 4.6. *Tenacity:* brittle.

Color: a very characteristic reddish bronze-yellow, *tarnishing* readily, usually to a dark brown. *Luster:* metallic. *Streak:* grayish-black. *Opaque.*

Form: Crystals are rare, usually in tabular hexagonal plates, but sometimes elongated, with a series of pyramids, appearing as deep striations. Commonly massive.

Distinguished from pyrite, bornite and niccolite, by its being *attracted by a magnet* and by its color.

Occurrence: Vast deposits occur at Sudbury, Ontario, where it constitutes an important nickel ore, probably through the presence of admixed pentlandite. Other extensive deposits occur at Ducktown, Tennessee, in Lancaster County, Pennsylvania, and Strafford, Vermont Magnificent, huge crystals come from Roumania.

Uses: Pure pyrrhotite is valueless, but it often carries gold, platinum and especially nickel and thus becomes of much importance.

Hematite, "specular iron," "red iron ore," is an iron oxide, Fe_2O_3. It is one of the most important and most varied of minerals. It is best studied by considering its prominent varieties separately.

(a) *Specular Iron:* in rhombohedral *crystals* with many forms, but always iron-black in *color*, with brilliant metallic *luster*, the maximum *hardness* for the species of 6.5, *specific gravity:* 5.2, opaque, unless in very thin plates, when it is blood-red by transmitted light: *streak:* cherry-red. *Micaceous hematite* is a variety of specular iron in which

thin, micaceous flakes are aggregated into masses. Republic, Michigan. furnishes an excellent illustration of this variety.

(b) *Compact-fibrous, or columnar, kidney ore* or *pencil ore.* Cleator Moor in Cumberland, England supplies the best material of these two types. Both of them are *very hard,* have a closely-knit, *fibrous structure.* more or less radiating, grayish-red *color,* brownish-red *streak.* Kidney-ore, figure 119, occurs in masses, often of large size, smooth-*mammillary* or kidney-shape. The miners usually treat the surface with stove polish and thus produce very bright and attractive specimens. Pencil-ore is in masses of exceptionally long-fiber.

(c) *Earthy,* red ocher or "rouge," is *soft,* without *luster,* and of bright, red *color.*

(d) *Argillaceous:* impure through admixture of clay, sand or other impurities. Under this general heading are included the very abundant *hard, reddish-brown* and gray, *massive* ores, as well as the *much softer* "*oolitic* hematite" which abounds in New York, also other *fossiliferous* hematite in which the masses are composed of multitudes of small, more

Figure 204. Hematite, "Iron Rose," St. Gothard, Switzerland. Group of Crystals

or less flattened concretions, largely the remains of corals. These are dull or submetallic in *luster,* have brownish-red *streak* and are *opaque.*

Distinguished from other iron ores and from massive cuprite by its streak.

Occurrence: Magnificent crystallized specimens are found in Switzerland, figures 98 and 204, and in the iron mines of the Island of Elba, England, Russia and Brazil. The world's greatest iron mines are in Minnesota and Michigan, while Alabama is also a large producer. Great steam or electrically-operated shovels scoop the ore out of the hillsides. Over 45,000,000 tons were mined in 1929 in the State of Minnesota alone.

Uses: Over 90 per cent of the iron produced in the United States was derived from hematite ore. The softer varieties are used as a red paint and as rouge.

Limonite, brown hematite, hydrated iron oxide, $2Fe_2O_3.3H_2O$.

Hardness: 5. to 5.5. *Specific gravity:* averages 3.8.

Luster: submetallic to dull; surfaces sometimes brilliant, as though polished.

Color: brown or yellow, sometimes with superficial, many-colored *tarnish.*

Streak: yellowish-brown. *Opaque.*

Form: never crystallized; usually amorphous, but not infrequently botryoidal or stalactitic, figure 205, concretionary (either oolitic or

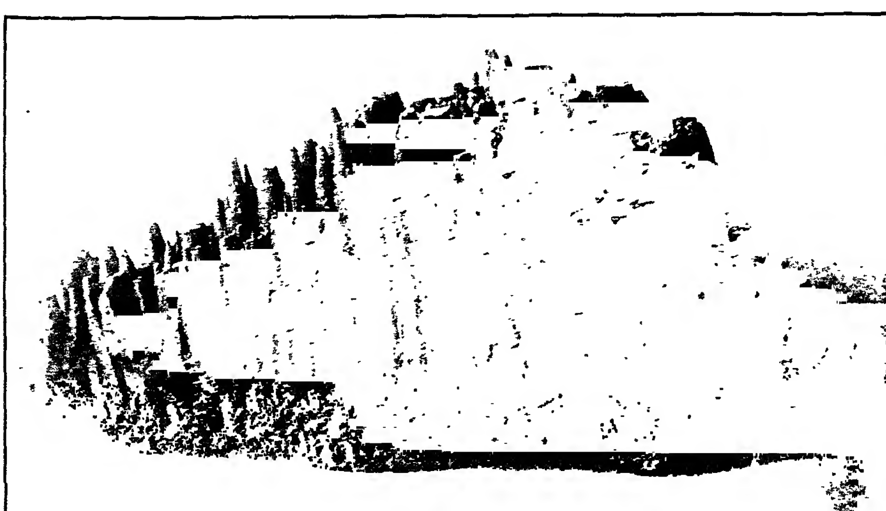


Figure 205. Limonite. Stalactitic

pisolitic), earthy. Common in pseudomorphs after pyrite, figure 134, magnetite and calcite.

Distinguished from goethite by its amorphous structure* and from other common iron ores by its streak.

Occurrence: It is a common mineral, formed by the alteration of other iron minerals and often found in marshes, whence the name *"bog iron ore."* In Alabama it forms beds of great size, which are extensively mined.

Uses: It is an important, though minor, ore of iron. The earthy variety is the pigment, *yellow ocher.*

Goethite, like limonite, is a hydrated iron oxide, its formula being $Fe_2O_3.H_2O$.

Hardness: 5. to 5.5. *Specific gravity:* about 4.2.

Ordinarily in *fibrous masses* of same *color* and *streak* as limonite and classified with it commercially as an iron ore of minor importance.

The *schiller* (page 116) of some feldspars is due to enclosure of minute crystals of goethite in parallel position.

Occurrence: Beautiful compact-fibrous, banded masses come from Negaunee, Michigan, fine groups of crystals from Cornwall, England. Numerous localities yield a considerable variety of forms which the more advanced student will enjoy.

Magnetite, magnetic iron ore, a compound of two iron oxides, $FeO.Fe_2O_3$.

Hardness: 5.5 to 6.5. *Specific gravity:* 5.18. *Tenacity:* brittle, breaking parallel to octahedral faces, but not true octahedral *cleavage.*

Color: iron-black. *Streak:* black.

Luster: brilliant *metallic* to dull. *Opaque,* except in very thin dendrites in mica, figure 139, when it is translucent and brown to black.

Magnetism: always strongly attracted by a magnet. Rarely it is itself a magnet, having polarity, and then called *lodestone,* see page 119 and figures 150–152.

Forms: Crystals are *isometric,* usually in octahedrons, less frequently in dodecahedrons often with striated faces, figure 206, rarely in highly modified crystals and "spinel twins," figure 103, cubes exceedingly rare. Also occurs, more plentifully, massive and coarse or fine-granular. "Black Sand" often consists largely of magnetite grains and minute crystals.

Distinguished from all other common minerals by its strong magnetism.

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* It has been established recently that the fibrous types heretofore classified as limonite are really goethite.

Occurrence: The enormous Scandinavian deposits are world-famous. Mineville, New York is an important producer. Among the best specimen localities are the Binnenthal, in Switzerland; North Issetsk, Urals; Traversella in Italy; French Creek Mines in Pennsylvania; Mineville, New York.

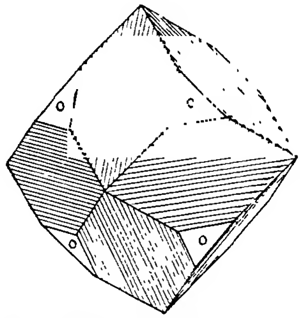


Figure 206. Magnetite, Striated Dodecahedron

Siderite, "spathic iron" "brown spar," is iron carbonate, $FeCO_3$.
Hardness: 3.5 to 4. *Specific gravity:* about 3.85.
Tenacity: brittle. *Cleavage:* rhombohedral.
Luster: vitreous to pearly. *Color:* brown to grayish-yellow.
Tarnish: reddish-brown to brownish-black. *Streak:* white.
Opaque to translucent.

Forms: Crystals are *rhombohedral,* usually in simple rhombohedrons, often curved. Generally in *masses* either showing good cleavage, or *granular,* sometimes compact. also botryoidal or globular (the variety *spherosiderite*).

Occurrence: Impure siderite forms great beds in England and is common in the Appalachian coal measures. It is often present in connection with ores of other metals, and at Roxbury, Connecticut and elsewhere, forms large beds of iron ore.

Uses: Siderite is a minor ore of iron and at times is used as a paint.

LEAD MINERALS

Lead has been known from ancient times, the Romans having used it for water pipes. It is soft, and when freshly cut, it has a brilliant metallic luster, but this soon tarnishes. As the lead compounds are poisonous, the use of lead pipe has been largely discontinued. The chief use of lead today is in storage batteries for automobiles. It is also used for lining tanks holding sulphuric acid because it is not attacked by that acid. Shot, bullets, type-metal and solder are made in part of lead, while it is essential in the manufacture of all lead paints. Next to iron, it is the cheapest of the metals.

The lead minerals with which the beginner should become familiar are *galena, cerussite, and anglesite.* There is a host of lead compounds found in nature, many of them of exceptional beauty, of which the collector will become enamoured later on.

Galena, lead sulphide, PbS, is by far the commonest of the lead minerals. It is one of the most attractive of minerals because of its very striking properties. It has a brilliant metallic *luster,* the granular and cleavable types glittering with an exceptionally beautiful sparkle. It may well be one of the early minerals which any collector purchases, for it is not very likely he will find it in his rambles, unless they be to the dumps of lead mines. Crystals, when broken, show a remarkable *cleavage* in the planes of the cube and will teach much about this important property of minerals. The easy cleavage makes it seem even more *brittle* than it really is. Galena is also strikingly heavy, its *specific gravity* being about 7.5. Its *hardness* is about 2.5.

Crystal form: isometric. Cubes are much the most common form, often more or less modified by the octahedron, figures 27 and 207. The octahedron alone is much rarer, though octahedrons modified by the cube are not uncommon. Other crystal forms are much rarer. The prevailing type of galena is *granular,* either coarse or fine. Occasionally the structure is so very fine-granular as to be *almost compact,* while the other extreme grades off into *coarsely cleavable* masses.

Color: typical "lead-gray." *Streak:* same as color and easily obtained on a streak plate because of its softness.

Occurrence: Galena is found in many different kinds of rocks all over the world, being one of the most widely distributed and plentiful of the metallic sulphides. It is extensively mined in the Missouri-Kansas-Oklahoma district, also in Idaho, Utah and Colorado. Much of

Figure 207. Galena, Crystals on Dolomite, near Joplin, Missouri

the granular ore carries silver, making it more valuable for the silver than for the lead.

Cerussite, "white lead ore," is lead carbonate, $PbCO_3$.

Hardness: 3 to 3.5. *Specific gravity:* about 6.5; heavy!

Fracture: conchoidal. *Tenacity:* very brittle when crystallized, fairly tough in masses.

Luster: quite variable; usually adamantine, sometimes resinous, vitreous, or pearly.

Color: usually white or gray. *Streak:* uncolored.

Transparent to nearly opaque.

Crystal form: orthorhombic. Crystals usually complex and often twinned. Reticulated crystallization, figures 97, 208, common. Usually massive.

Figure 208. Cerussite, Reticulated Crystals, Broken Hill, New South Wales

Occurrence: Cerussite is formed by the action of a solution of calcium bicarbonate on galena. It is, therefore, often found with an unaltered core of galena. It is a common ore in lead mines and often carries much silver. The largest and finest crystals come from the Organ Mountains, New Mexico. Beautiful aggregates of snow-white, slender prismatic crystals are found in Arizona, Colorado, Idaho and elsewhere. Broken Hill, New South Wales yields magnificent reticulated groups. There are many other occurrences worthy of mention.

Distinguished from anglesite by effervescing in acids. The massive mineral often resembles a quartzite rock, but a drop of acid will establish its true character.

Anglesite, lead sulphate, $PbSO_4$, is a fairly abundant ore of lead.

Hardness: about 3. *Specific gravity:* about 6.3, nearly the same as cerussite, much heavier than most non-metallic minerals.

Tenacity: very brittle. *Fracture:* conchoidal.

Color: colorless, white or gray. *Luster:* adamantine.

Streak: uncolored.

Transparency: transparent to opaque.

Crystal form: orthorhombic, usually simple double-pyramids or else prismatic and highly complex. Often massive.

Occurrence: formed by the alteration of galena with which it is usually associated; often in nodules, with concentric banding, surrounding a core of unaltered galena, as in the Castle Dome District, Arizona, at Dividend, Utah and in Queensland. Magnificent crystals come from Sardinia; Broken Hill in New South Wales; Phoenixville, Pennsylvania and many other localities.

Uses: an important ore or lead.

LITHIUM MINERALS

Lithium does not occur free in nature. It is the lightest of all metals, though too rare to have any large commercial uses. Its compounds are used in medicine. They are recognized by the purplish-red color they impart to a flame.

Lepidolite—see page 230.

Amblygonite, is a comparatively rare aluminum and lithium phosphate, containing also lithium fluoride (see page 25). Its most common occurrence is in white, cleavable masses, resembling feldspar from which it is readily distinguished by the ease with which it melts in a hot flame, or by its *cleavage* angle, which is quite different from the right angle cleavage to which all the feldspars approximate.

Its *hardness* is 6. which distinguishes it from calcite.

Specific gravity: about 3.0. It is the mineral commonly used for extraction of lithium salts. Found in pegmatite in Maine, California and France.

Spodumene is an aluminum and lithium silicate. $LiAlSi_2O_6$. *Hardness:* 6.5 to 7; *specific gravity:* 3.20. It is notable among all minerals for the enormous *size* of some of the *crystals,* which have been found up to forty-seven feet in length, with weight estimated at ninety tons! In form they are monoclinic, not unlike some pyroxene, flat and prismatic. *Cleavage* is easy parallel to the prism. Common *color* is white. It has been used as a lithium ore. Found in pegmatite in Connecticut, South Dakota and elsewhere.

Hiddenite is a very rare variety of spodumene having a rich yellowish to emerald-green color. Magnificent gems have been cut from small crystals found at Hiddenite, North Carolina.

Kunzite is a lilac-colored variety found in California and Madagascar. Superb, transparent crystals occur, worth thousands of dollars and yielding magnificent gems.

MAGNESIUM MINERALS

Magnesium is not found native. It is a brilliant metal, slightly lighter than aluminum and is rapidly assuming major importance in many light alloys, especially with aluminum. It is also used in fireworks and for flashlights in photography. The metal is manufactured in the United States exclusively from magnesium chloride, recovered from treatment of salt-well brines, as at Midland, Michigan. Magnesium is a constituent of many important rock-forming minerals.

Magnesium Minerals. The commonest magnesium minerals are magnesite and dolomite. Spinel is described under aluminum. Serpentine, talc, amphibole, pyroxene, and chrysolite, which are rich in magnesium, are of greater importance as rock-forming minerals and are described in that section.

Magnesite is magnesium carbonate, $MgCO_3$.

Hardness: 3.5 to 4.5. *Specific gravity:* about 3.08.

Form: usually in very compact masses; rarely crystalline, resembling coarse dolomite; sometimes in distinct cleavages. Its rhombohedral *crystals* are almost never seen.

Cleavage: rhombohedral, distinct. *Fracture:* conchoidal, flat.

Tenacity: tough in amorphous form; becoming brittle when in crystals.

Luster: dull when massive, vitreous in crystals. Nearly *opaque* to translucent.

Streak: white. *Color:* white, occasionally gray or yellow; rarely brown.

Occurrence: The Grecian deposits have been the chief source of the imported, crude commercial mineral, though the amorphous mineral is mined in California and the crystalline in Washington.

Uses: Magnesite has many uses as a refractory and in insulation, also in medicines, in paper making and in the manufacture of carbon dioxide.

Dolomite, like calcite, is a carbonate of calcium, but half of its calcium is replaced by magnesium; formula is $(Ca,Mg)CO_3$.

Test its *hardness* and you will find that it scratches calcite, but not fluorite, so it is 3.5. *Specific gravity:* about 2.8 to 2.9.

The fundamental form of its *crystals* is the rhombohedron and, un-

like calcite, it is usually found in simple rhombohedrons and rarely in prisms or scalenohedrons. The rhombohedrons are often curved and quite commonly small crystals group themselves regularly at a slight angle to each other in such a manner as to form "saddle-shaped" crystals, as shown in figure 209. Twins, figure 210, are common.

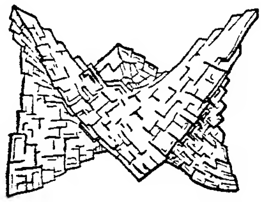


Figure 209. Dolomite, Saddle-shaped Group of Crystals

Its *color* is usually white, but often tinted pink as in the Joplin, Missouri region.

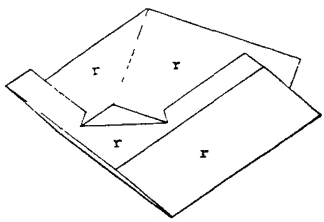


Figure 210. Dolomite, Twinned Rhombohedrons

Dolomite has excellent rhombohedral *cleavage* like calcite, and greatly resembles it, but it can be distinguished by the differences noted above.

It is not so easily acted on by acids as calcite, for it does not fizz briskly until heated in dilute acid.

Occurrence. It is very abundant in nature as dolomitic limestone, many great rock masses being composed entirely of this mineral, as in the "Dolomite Alps" of the Tyrol. Much marble is also dolomite.

Brucite is magnesium hydrate, or hydrated oxide of magnesium, $Mg(OH)_2$.

Hardness: 2.5. *Specific gravity:* 2.4. *Cleavage:* basal, perfect. *Sectile. Color:* white, sometimes pale blue or green. The most notable American locality for specimens was in Lancaster County, Pennsylvania, which produced beautiful, pearly, hexagonal, tabular crystals and rosettes. It has always been regarded as a rare mineral, but immense deposits in Nevada now furnish it by the carload. A fibrous variety, *nemalite*, occurs at Hoboken, New Jersey.

MANGANESE MINERALS

Metallic Manganese does not occur in nature and is not used as such in the arts, but when alloyed with iron it is of transcendent importance. "Spiegeleisen" is such an alloy carrying less than 20 per cent of manganese. Alloys carrying over 20 per cent and on up to 90 per cent manganese are called "ferro-manganese." These alloys when added to steel impart to it greatly increased strength and hardness, making excellent material for armor plate and burglar-proof safes.

Manganese Minerals: Manganese is present as an essential constituent in about one hundred and fifty different minerals. Very few of these are common or of commercial importance and many of them are exceedingly rare, but some of them are found in mineral specimens of great magnificence. Those minerals only which it is most important for the beginner to know are treated here. These are: *pyrolusite, psilomelane, rhodochrosite, rhodonite. Franklinite* is described under zinc minerals.

Pyrolusite, manganese dioxide, MnO_2, in its *commonest form,* is an *opaque,* black, *massive* mineral, so *exceedingly soft* that it soils the fingers. In this form it is one of the most abundant of the manganese ores. Occasionally it occurs in groups of orthorhombic *crystals,* with brilliant metallic *luster* and blackish-steel-gray *color,* with black or bluish-black *streak,* of greater *hardness,* but not in excess of 2.5, and *specific gravity* of 4.82. *Dendrites,* figures 137, 138, see page 101, are often pyrolusite.

Occurrence: Pyrolusite is usually closely associated or mixed with psilomelane in localities too numerous to mention. Nova Scotia has produced excellent radiated masses and good groups of crystals. Probably the finest specimens come from Germany.

Psilomelane consists of manganese oxide with the addition of water and usually either barium oxide or potassium oxide. Its composition is quite indefinite owing to impurities which are almost always present.

Hardness: 5 to 6, much greater than pyrolusite.

Specific gravity: about 4.2. *Tenacity:* brittle. *Fracture:* smooth-conchoidal.

Color: black to dark gray. *Streak:* brownish-black, lustrous. *Opaque.*

Form: massive, botryoidal, mammillary, stalactitic; often banded with pyrolusite.

Distinguished from pyrolusite by its streak and superior hardness; from limonite by its streak.

Occurrence: a widely distributed and very plentiful ore of manganese. Many German localities yield choice specimens. Great deposits occur in Russia, India, Brazil and elsewhere.

Rhodochrosite, "manganese spar," is manganese carbonate, $MnCO_3$. It is distinguished from all other manganese minerals by its *crystals* of rhombohedral forms and its beautiful pink color. The beginner must, however, be constantly alert for different forms and colors than those with which he has already become familiar. In this mineral it is possible, though not likely, that he may meet it in scalenohedrons (see page 55) and that they may be of a deep red color; or he might find the mineral white or gray or even brown and in globules. Quite frequently it is granular-massive. In general, however, it is safe to speak of it as a pink mineral occurring in rhombohedrons, not infrequently curved, or in masses with rhombohedral *cleavage.*

Hardness: 3.5 to 4.5. *Specific gravity:* about 3.55. *Tenacity:* brittle. *Luster:* vitreous to pearly. *Streak:* white. *Transparent* to opaque.

Dissolves with effervescence (fizz) in warm acid, like all carbonates.

Occurrence: It is frequently found in veins with other ores of manganese, also with silver, lead and copper ores. Occurs at Butte, Montana in sufficient quantity to be utilized as an ore of manganese. The finest specimens in the world come from Alma, Colorado, where it occurs in groups of large rhombohedrons of richest, rose-red color; also in groups of small rhombohedrons of much beauty at Alicante, Colorado and in groups of opaque, curved rhombohedrons of pale pink color near Lake City, Colorado and at Kapnik, Roumania; also in groups of scalenohedrons in Westphalia.

Rhodonite is manganese silicate, $MnSiO_3$.

It often resembles rhodochrosite in its pink *color,* but is distinguished from it by its greater *hardness,* 5.5 to 6.5, its nearly cubical *cleavage,* while rhodochrosite is rhombohedral; also by its markedly different forms of *crystals,* which are triclinic. The hardness test is usually sufficient.

Specific gravity: about 3.6.

Tenacity: Crystals are brittle; masses are very tough.

Transparency: Small crystals are often transparent; large crystals and masses are translucent to opaque.

Color: usually some shade of pink or brownish-red, changing on exposure to black.

Luster: vitreous. *Streak:* white.

Occurrence: The most notable locality is the Ural Mountains. Here it is found in granular-massive form, resembling a pink marble. It oc-

curs similarly in Cummington, Massachusetts, in Washington and elsewhere. By far the most magnificent specimens are the crystals of the zinc-bearing variety called *fowlerite* at Franklin, New Jersey. These sometimes attain a size of six inches or more.

Uses: The compact-granular varieties from Russia are highly prized as ornamental stones and are cut into table-tops, vases, paper-weights, jewel boxes and decorative objects of many kinds. The mineral from Washington is pale pink and is associated with a blackish-green amphibole. It would make a fine decorative stone.

MERCURY MINERALS

Mercury, or **Quicksilver,** is the only metallic element found in nature as a liquid at ordinary temperatures. It becomes solid (freezes) at -39° Fahrenheit. It is exceedingly heavy, having a specific gravity of 13.6.

Uses: As it is the "metal of a thousand uses," many of which are highly technical, it is not surprising that its well-known household use in thermometers consumes but a fraction of one per cent of the output. Formerly it was extensively used in the amalgamation process for recovery of gold. Some of its principal uses are in preparing drugs and chemicals, in scientific apparatus and for fulminate in blasting caps and ammunition.

Native Mercury, symbol Hg, is found in many quicksilver mines, occasionally in sufficient quantities to be an important source of the metal.

Cinnabar, mercury sulphide, HgS, is the most abundant ore of mercury. Its most distinguishing property is the scarlet-red color of its *streak.* Its surface *color* varies from scarlet to cochineal-red, brownish-red, fading into dull gray. The earthy forms usually have a scarlet color and are *opaque* and dull; while the crystallized types often have a deep, rich, almost ruby-red color and at times are *transparent,* with *adamantine luster.*

Hardness: 2 to 2.5. *Specific gravity:* about 8.1, one of the heaviest of minerals. *Crystals:* rhombohedral, often complex, or in six-sided prisms.

Occurrence: Almaden, Spain, is the richest and most celebrated locality. Idria and Monte Amiata in Italy are large producers, the latter yielding a peculiar crystalline-fibrous type. In the United States, there are many mines in California, Washington, Texas and elsewhere. The most wonderful specimens are the large twin crystals from Hunan Province, China.

Uses: It is the most important ore of Mercury.

MOLYBDENUM MINERALS

Molybdenum does not occur in nature. It is a silvery-white metal, of about the same weight as copper, possessing great tensile strength. It is of considerable importance in the manufacture of special steels which are used extensively in aircraft and automobiles. Molybdenum wire and sheets are used in the radio industry. Molybdenum compounds are used in the manufacture of chemicals and dyes.

The chief ores of molybdenum are *molybdenite* and *wulfenite.*

Molybdenite, molybdenum sulphide, MoS_2, is much the commonest of the molybdenum minerals.

Hardness: 1 to 1.5; very soft, soiling the fingers. *Specific gravity:* 4.7.

Tenacity: flexible, but not elastic; *sectile.*

Cleavage: basal. *Structure:* foliated or fine-granular.

Luster: metallic, brilliant. *Color:* lead-gray.

Streak: greenish, but makes a bluish-gray mark on paper.

Feel: greasy.

Form: crystals are hexagonal. Usually in scales, scattered through the rock, like graphite.

Distinguished from graphite, which it much resembles, by its color and greater weight.

Occurrence: It is a widely distributed mineral, usually in small quantities. The mine at Climax, Colorado is the chief source of supply. It is also produced in New South Wales (fine specimens!), Canada and many other countries.

Wulfenite, lead molybdate, $PbMoO_4$, is a mineral whose specimens often possess great beauty of color and form. It is usually in thin, tabular *crystals* of tetragonal form, though stout, double pyramids, often rounded and modified, are not uncommon. The prevailing *color* is light yellow, which grades off to orange and rich scarlet or aurora-red, or to greenish, white or gray.

Hardness: 3. *Specific gravity:* 6.7.

Tenacity: exceedingly brittle. *Luster:* resinous to adamantine.

Streak: white. *Transparent* to nearly opaque.

Occurrence: Magnificent specimens come from several localities in Arizona, New Mexico, Mexico, Jugoslavia and elsewhere. It rarely occurs in sufficient quantity to be an ore, though small quantities have been mined for their molybdenum.

NICKEL MINERALS

Nickel is not found in nature. It is a white metal, hard, malleable, taking a high polish and not readily tarnishing. Its most important use is in alloys with other metals, as in nickel-chromium steel, "monel metal," "German silver," and nickel steel. Our five-cent piece, popularly called "a nickel," is three-fourths copper and one-fourth nickel. Nickel-plated objects are familiar to everyone.

Nickel Minerals. It may surprise a beginner to know that nickel forms an essential part of some two-score of minerals, for it is not at all unlikely that he may collect in a large number of localities, for many years, without ever meeting one of the nickel minerals. Not one of them is a common mineral. It is worthy of note that the largest nickel mines in the world, those at Sudbury, Ontario, derive their chief supply of nickel from *pyrrhotite,* in which nickel occurs as an impurity and is not essential. This mineral is described on page 179. The nickel-bearing pyrrhotite does not differ in general appearance from pure pyrrhotite.

Niccolite, a compound of nickel and arsenic, NiAs, is an important nickel ore at Cobalt, Ontario. It occurs as a pale *copper-red, metallic* mineral, with a brownish-black *streak* and dark *tarnish. Hardness:* 5 to 5.5. *Specific gravity:* about 7.5. It is usually massive and often is associated with smaltite.

Pentlandite, a sulphide of iron and nickel, (Fe,Ni)S, greatly resembles pyrrhotite, in which it is usually imbedded at Sudbury. It may be distinguished by its brillant cleavage faces. Its presence in pyrrhotite renders this otherwise barren mineral a rich nickel ore.

Garnierite is a hydrated nickel-magnesium silicate. It is a *soft,* exceedingly *brittle,* pale to dark *green,* massive mineral. It is found in New Caledonia in such large quantities as to make this island the second largest producer of nickel.

PLATINUM MINERALS

Platinum, symbol Pt, is one of the few metals which is found native, though it never occurs in large quantities. It has a *hardness* of 4. to 4.5 and, when pure, a *specific gravity* of 21.5, but owing to impurities, it is usually as low as 14. to 17., chiefly because of the presence of iron, which renders it *magnetic.*

Color and *streak:* pale steel gray. *Tenacity:* malleable and ductile. *Infusible,* and not dissolved by any one acid: therefore of great value in laboratory apparatus.

Occurrence: It is generally found in grains or scales, in alluvial deposits, associated with iridosmine, gold and chromite. Occasionally in nuggets, up to 294 ounces. The Ural Mountains have long been the world's chief source of supply, with minor quantities coming from Colombia, Brazil and elsewhere. Recently large deposits of platinum-bearing rocks have been discovered in South Africa.

Uses: Its chief uses are for laboratory apparatus, jewelry, in dentistry, and for the tips of fountain pens, for which it is alloyed with iridium and osmium.

Identification: It is inferior in hardness to iridosmine, not so light in color and not brittle. If in crystals, they are cubical, while those of iridosmine are hexagonal plates.

Value: It has varied greatly in value. During the great war its price rose to over $200 per ounce; probably its average price will be about the same as gold.

Platinum is not likely to be found in the field by the beginner, but its great value and importance make it desirable that he be able to recognize it if he should come across it, and no prospector should be ignorant of its appearance. Look it up in a public museum.

Sperrylite is a rare platinum arsenide, $PtAs_2$, which has been found in minute, isometric crystals, with tin-white color and brilliant metallic luster, near Sudbury, Ontario, and in the Transvaal, South Africa, in larger and very fine crystals. It is a valuable platinum ore.

POTASSIUM MINERALS

Potassium does not occur native, but its compounds are so essential to the fertility of soils that some knowledge of them is important. *Common feldspar* and *muscovite mica* contain in the aggregate far more potassium than other minerals, but unfortunately the difficulties of extracting it are so great that the commercial supplies are obtained from other sources.

For a half a century, up to the time of the world war, the "potash fertilizers" from the great deposits at Stassfurt, Germany supplied the world. Many millions of tons of *sylvite* and *carnallite*, both soluble salts, have been removed. Similar deposits occur in Alsace-Lorraine and recent discoveries in Texas and New Mexico indicate that large deposits of these minerals are present there. The vast deposits of *leucite* in Wyoming and the *alunite* in Utah give our country reserves of potassium minerals which can be drawn upon when needed.

The potassium compounds have many other important uses, such as in making liquid and soft soaps, in photography and medicine, in fireworks and explosives, and in glass making.

Sylvite is potassium chloride, KCl, the potassium mineral corresponding to halite. Like it, sylvite is soluble in water and has a saline taste, though bitter. *Hardness:* 2. *Specific gravity:* 1.98. *Colorless,* when pure. *Cleavage:* cubic and perfect. *Crystals* are isometric, but scarce. It is usually in granular-crystalline masses.

Carnallite is a hydrous chloride of potassium and magnesium, $KMgCl_3.6H_2O$.

Hardness: 2.5. *Specific gravity:* 1.60. *Color:* white or brick-red. *Luster:* greasy. *Taste:* bitter. *Deliquescent,* slowly absorbing water from the air. *Crystals:* orthorhombic, usually complex, rare; commonly in granular masses.

Leucite: see page 225.

Alunite is a comparatively rare hydrous sulphate of aluminum and potassium, $KAl_3S_2O_{11}.3H_2O$.

Hardness: 3.5 to 4. *Specific gravity:* 2.6. *Color:* white, gray or pale pink. Usually *fine-granular.*

Occurrence: There is a large deposit in Southern Utah of commercial importance. Also is found abundantly in Italy and New South Wales.

Other Potassium Minerals: There are scores of other potassium-bearing minerals, many of them of considerable importance.

SILVER MINERALS

Silver is the precious metal of the masses, being used as the standard coin in many sections of the world. It is also extensively employed in the household for silverware of many kinds, and in the cheaper jewelry. It is the best conductor of electricity. Silver compounds are of inestimable value in photography and medicine.

Native Silver, symbol Ag, does not often greatly resemble silverware, for it is apt to have a rough surface and a *tarnish,* which varies from a reddish-bronze, almost like copper, to an almost golden-yellow, or sometimes to a dull black. If not tarnished, native silver is white, and has a brilliant metallic *luster.*

Hardness: 2.5 to 3. *Specific gravity:* 10.5. *Tenacity:* malleable to a remarkable degree and highly ductile. *Fracture:* hackly.

Form: Distinct, isometric crystals are comparatively rare, usually they are poorly developed and arborescent or reticulated. Irregular masses, flakes, leaves or scales are common. Wire silver is frequently found, in either very slender or stout threads, figure 211.

Occurrence: Though widely distributed, it is not the most important

ore of silver. The mines at Kongsberg, Norway, have been producing it for hundreds of years, yielding the world's most magnificent specimens, both of crystals and wire silver, the latter sometimes reaching the size of a man's arm. Cobalt, Ontario has been a prolific producer of masses. Beautiful specimens often attractively associated with copper, come from the Lake Superior region. Aspen, Colorado was formerly a great producer; one mass of pure silver weighed 1842 pounds. Mexico, Chile, Germany and many other countries have been large producers.

Figure 211. Wire Silver on Calcite, Paterson, New Jersey. Courtesy of J. A. Grenzig

Silver Ores, as a rule, do not show the individual silver minerals to which they owe their value, with sufficient distinctness to enable the beginner to recognize them. If a visit is made to a silver mine, it is likely that several different minerals will be found, the most important of which are:

Argentite, "silver glance," silver sulphide, Ag_2S, is a *blackish-gray* mineral, so *soft* that it is readily cut with a knife, thus revealing its *shining streak* of the same color. It is probably the most abundant silver ore.

Polybasite, a compound of silver with sulphur and antimony,

Ag_9SbS_6, an *iron-black* mineral with black *streak* and metallic *luster*, distinguished by its *cherry-red color* in thin slivers. Usually *massive*, but when in *crystals* they are always six-sided and tabular.

Stephanite, "brittle silver," is also a compound of silver with sulphur and antimony, Ag_5SbS_4, and much resembles polybasite, but is absolutely *opaque* even in thin slivers. *Usually massive* and disseminated through the rock.

Proustite, "light ruby silver," is a compound of silver with arsenic and sulphur, $3Ag_2S.As_2S_3$. It is characterized by its rich, cochineal-red to *scarlet color* and scarlet *streak*. Superb *crystals* from Chile are *transparent* and of large size, and rank among the very finest of all mineral specimens. When massive, sometimes much resembles cuprite, realgar or cinnabar.

Pyrargyrite, "dark ruby silver," is a compound of silver with antimony and sulphur, $3Ag_2S.Sb_2S_3$. It is *not so transparent* as proustite, of darker *color*, often grayish-black, and has a purplish-red *streak*, much darker than that of proustite. It is fairly common in good six-sided, prismatic *crystals*, but is usually *massive*, often in thin flakes on the rock.

Cerargyrite, "horn silver," is a chloride of silver, AgCl.

It is *very soft*, *hardness* 1. to 1.5, and therefore, readily cut with a knife; but its most remarkable characteristic is that it is highly *sectile*, being easily cut into shavings. When exposed to light it darkens to a peculiar violet-brown *color* and becomes *opaque;* but if not exposed to light it may be perfectly *colorless*, white or gray, and quite *transparent*. Its *luster* is resinous to adamantine. If in *crystals* they are usually cubes.

Embolite is a compound of silver with chlorine and bromine, Ag(Cl.Br). It has the same general appearance as cerargyrite and many of its properties are the same, but its *color* is ordinarily greenish or yellowish, darkening on exposure to light. Its *crystals* are more common than those of cerargyrite and are usually cubo-octahedrons (see page 45). It is plentiful enough to be an important silver ore.

Iodyrite is silver iodide, AgI. It is distinguished from the two minerals last mentioned by its bright *yellow color* and the *hexagonal form* of its crystals. It is much rarer.

Other sources of Silver. Only about one-third of the world's silver output is derived from ores having silver as a highly predominant factor.

Much of it is recovered from the mining of *silver-bearing galena, chalcocite, tetrahedrite* and other minerals which are essentially ores of lead or copper.

SODIUM MINERALS

Sodium does not occur native for the good reason that it has a very strong affinity for oxygen. It is, however, of great interest to the chemist. It is a silver-white metal, lighter than water and, while floating on its surface, reacts violently, decomposing the water with release of hydrogen and production of sodium hydroxide.

Sodium compounds are essential to life and civilization, yet it is quite possible that the beginner will meet but one of them, *halite,* in field collecting, and the others are of small mineralogical importance.

Halite, "rock salt," is sodium chloride, $NaCl$.

Hardness: 2.5. *Specific gravity:* 2.16. *Cleavage:* cubic and very perfect, figure 106, (see page 77). *Color:* when pure, colorless to white. *Transparent* to translucent. *Taste:* saline; soluble in water.

Crystals: isometric, nearly always in cubes, figure 85, but frequently skeletonized or hopper shaped, figure 86, page 65.

Occurrence: Halite is present in sea water everywhere, averaging about 2.5%, and also in larger percentage in salt lakes. Vast deposits of rock salt occur in many parts of the world, notably in New York State, Michigan, Austria, and Germany. These are the result of the drying up of confined bodies of salt water. 25,000,000 tons is the approximate annual world production of salt, of which about 8,000,000 tons were produced in the United States. It is usually associated with gypsum, and in the Western states the "salt domes" frequently lead to the discovery of petroleum.

Uses: Salt is vital to the life of man and of many animals. It is used as an essential article of diet, as a preservative of food and is the chief source of sodium compounds used in dyeing, bleaching, oil refining, and in the manufacture of glass, soap, and many other products.

Cryolite, "ice-stone," is a fluoride of sodium and aluminum, Na_3AlF_6.

Hardness: 2.5. *Specific gravity:* 3.00.

Crystals: rare; monoclinic, closely resembling cubes, often in parallel position. Usually massive, sometimes with well-developed *cleavage,* appearing cubic.

Color: usually snow-white to colorless and *translucent,* somewhat resembling alabaster. Occasionally smoky.

Easily *fusible,* even in candle flame.

Occurrence: The only commercial source of supply is near Ivigtut, Greenland.

Uses: Its easy fusibility suggested its use as a flux in the electrolytic manufacture of aluminum from bauxite. It is also used in the making of sodium salts, and some kinds of glass and porcelain.

Other Sodium Minerals: Sodium is an essential part of about one hundred and fifty minerals, the large majority of which are rock-forming minerals. Some of these are described in that section, including *several of the feldspars, nephelite, cancrinite, sodalite, lazurite, wernerite* and *some of the zeolites.* All of these minerals are silicates.

Trona is the most commonly occurring sodium carbonate.

Soda niter, "Chile saltpeter," is an important sodium nitrate.

Borax, see page 144, is a sodium borate.

Kernite, see page 145, is also a sodium borate.

Thenardite, glauberite and **mirabilite** are sodium sulphates.

STRONTIUM MINERALS

Celestite is strontium sulphate, $SrSO_4$. It often resembles barite in the form of its *crystals* and in its *cleavage.* Its *specific gravity* is less, 3.96.

Hardness: 3. to 3.5. *Luster:* vitreous to pearly.

Colorless, white, pale blue, or red. *Transparent* to translucent.

Occurrence: It is usually found in limestone or sandstone, associated with calcite, gypsum, or sulphur. The finest specimens are from Lake Erie, California, England, and Sicily. *Fibrous celestite* is not uncommon.

Distinguished from barite most readily by heating a fragment intensely in a flame to which it then imparts a crimson color, while barite gives a yellow-green.

Uses: for fireworks and in refining sugar.

Strontianite is strontium carbonate, $SrCO_3$. It is usually in radiated crystalline masses of yellowish-white *color.*

Hardness: 3.5 to 4. *Specific gravity:* 3.7.

Uses: similar to celestite.

Occurrence: The best specimens come from the commercial deposits at Hamm, Westphalia.

SULPHUR MINERALS

Sulphur, symbol S, is by far the most abundant of the non-metallic native elements

Hardness: 1.5 to 2.5. *Specific gravity:* about 2.0.

Its prevailing *color* is so characteristic that it is known as "sulphur yellow," yet sulphur is often yellowish-gray, greenish-gray or brownish-red. Crystals usually have the typical color, but masses are apt to be impure and of duller tints. *Streak:* white or pale yellow.

Luster: adamantine on crystal faces, resinous elsewhere. Crystals often *transparent* or translucent, while masses are nearly opaque.

Cleavage: not distinct. *Fracture:* conchoidal to uneven.

Tenacity: crystals are exceedingly brittle; masses may be somewhat sectile.

Conductivity: A cold crystal placed in the hand cracks, because it is a non-conductor of heat, the warmth of the hand being unequally distributed. If held to the ear this cracking is easily heard. It is also a non-conductor of electricity. When rubbed it becomes negatively charged.

Distinguished from all other minerals by melting a little above the boiling point of water and, when further heated, igniting, burning with a blue flame and yielding suffocating fumes of sulphur dioxide.

Form: Crystals are orthorhombic, commonly in double pyramids, but often modified by other faces. It is also found fibrous, earthy, or in masses of various shapes.

Occurrence: Sulphur is widely distributed. It is chiefly found associated with gypsum, as a result of volcanic activity. Sicily was formerly the major source of supply and still furnishes by far the most beautiful specimens, but commercially it has lost its importance because of the discovery of enormous deposits in Texas and Louisiana. These states now supply some 2,000,000 tons annually, worth nearly $25,000,-000. It is found here at a depth of 600 to 1100 feet and averages 125 feet in thickness. It has been estimated that these great deposits contain six times as much sulphur as is known in all the rest of the world. It is brought to the surface by forcing steam down through pipes, melting the mineral and then pumping it to the surface, where it is discharged into huge vats and solidifies. It is frequently found around fumaroles and hot springs, as in the Yellowstone Park.

Uses: By far the most important use of sulphur is in the manufacture of sulphuric acid, the most important of all chemicals. It is also employed in making paper, matches, gunpowder, fireworks, insecticides, fertilizers and in vulcanizing. Since the discovery of the Texas deposits it has largely supplanted pyrite in the manufacture of sulphuric acid.

Other Sulphur Minerals: Sulphur occurs in vast quantities combined with many of the metallic elements, forming the very important class of *sulphides,* page 25, which includes many of the most important ores of the metals, such as *galena, chalcocite, chalcopyrite* and *sphalerite,* also *pyrite* and *pyrrhotite.*

Another large class of sulphur compounds is the *sulphates,* page 28, in which sulphuric acid has united with the metallic oxides. Among the most important of these are *barite, celestite, gypsum, anhydrite* and *anglesite.*

TIN MINERALS

Everyone is familiar with the appearance of artificial metallic tin, but the native metal is practically unknown. Thin sheets of iron or steel are plated with tin by merely dipping into the melted metal. They are then made into tin cups, pails, plates and many other inexpensive articles. Tin cans are manufactured by the million and much tin is used in making bronze and soft solder.

Cassiterite, tin oxide, SnO_2, is the only abundant ore of tin and unfortunately very little of it is known to exist in the United States.

Hardness: 6 to 7, hard. *Specific gravity:* about 7, notably heavy.

Luster: in crystals, adamantine; masses, often dull.

Color: usually brown or black, but occasionally yellow, ruby-red, gray or white.

Streak: obtainable by pulverizing, usually pale brown to nearly white.

Transparency: commonly nearly opaque, but occasionally perfectly transparent. Such material shows its high *index of refraction* by yielding gems with a wonderful play of colors.

Crystal form: tetragonal, with twins very common and their complexity disguising the form. Well developed four-sided prisms, terminated by four-sided pyramids, are sometimes found.

Structure and form: Most of the tin of commerce is obtained from "*stream-tin,*" which usually consists of more or less rounded, small grains or pebbles, with little structure. "*Wood-tin*" is in nodules, or of botryoidal forms, figure 212, having fibrous-radiated structure.

Occurrence: Cassiterite is widely distributed. The famous mines of Cornwall, England have been worked for hundreds of years and formerly were the chief source of supply. Now the Malay Peninsula has taken the lead, the ore being almost exclusively "stream-tin." Magnificent twin crystals come from Bohemia and a number of German localities, while the finest in the world are found in Bolivia. Beginners who

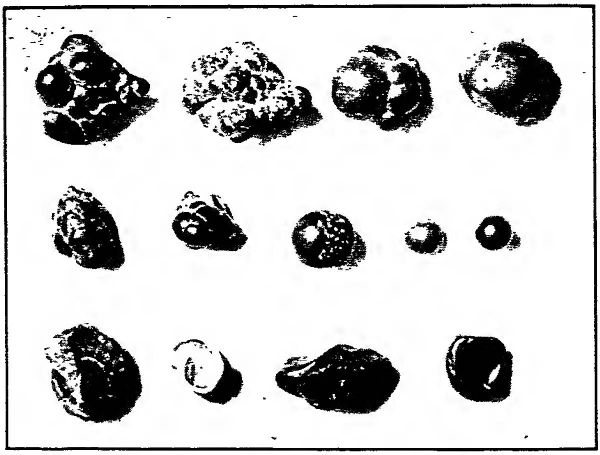


Figure 212. Cassiterite, Wood Tin, Durango, Mexico

desire to have the mineral from the United States will find its occurrence in the Black Hills of South Dakota fairly attractive.

Other Tin Minerals: While tin occurs as *stannite,* and in a number of other minerals, they are unimportant as sources of supply.

TITANIUM MINERALS

Metallic titanium does not occur native, but its oxide is fairly abundant as the mineral *rutile,* and occurs still more plentifully combined further with iron, as the mineral *ilmenite.*

Titanium when added to steel removes the oxygen at the time of casting. It is of increasing importance as a pigment.

Rutile is titanium dioxide, TiO_2.

Hardness: 6. to 6.5, hard. *Specific gravity:* about 4.2.

Cleavage: prismatic, well developed. *Fracture:* subconchoidal, to uneven. *Tenacity:* moderately brittle.

Luster: a peculiar metallic-adamantine.

Color: usually reddish-brown to black. *Streak:* light brown.

Transparent to opaque.

Form: *Crystals* are tetragonal, commonly prismatic and generally complex through twinning, which is often repeated as shown in figure 213.

Occurrence: Rutile is widely distributed in small masses or crystals. One of its most important commercial localities is in Nelson County, Virginia. It is often found in slender needles or hair-like crystals, sometimes enclosed in clear quartz, forming *rutilated quartz,* as in Brazil and Madagascar. The best crystals come from Graves Mountain,

Georgia. Excellent specimens are also found in North Carolina, Arkansas, Pennsylvania and many other localities.

Uses: Rutile is the best ore of titanium. It is chiefly used in the ceramic industry to add color and strength.

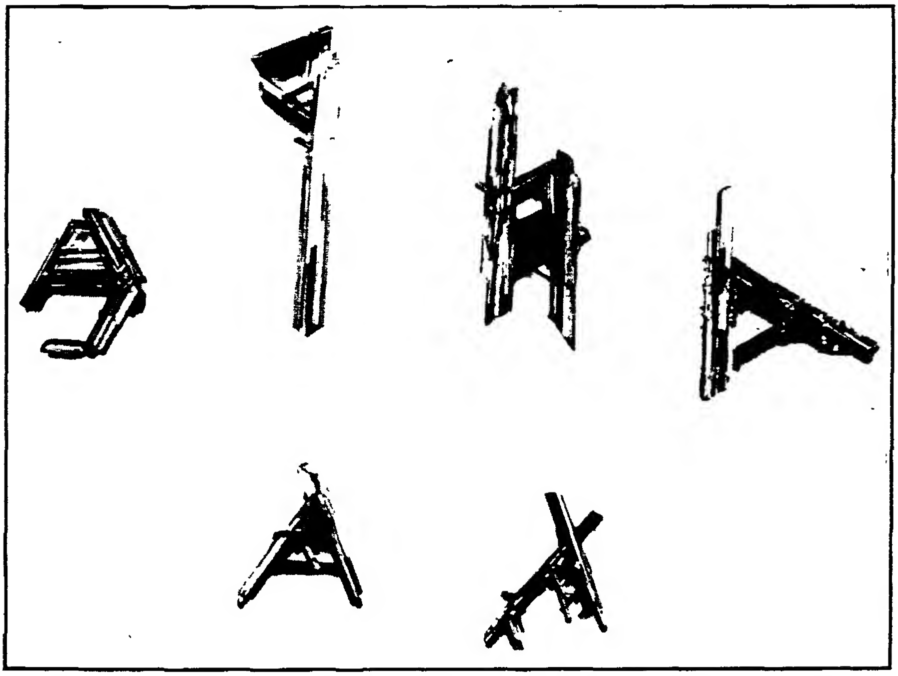


Figure 213. Rutile, Prismatic Crystals Showing Repeated Twinning, Alexander County, North Carolina

Ilmenite, or menaccanite, iron-titanium oxide, $FeTiO_3$ is the most abundant titanium mineral.

Hardness: 5 to 6. *Specific gravity:* 4.5 to 5. *Fracture:* conchoidal. *Tenacity:* brittle. *Luster:* submetallic. *Color:* iron-black.

Streak: black to reddish-brown. *Opaque.* Slightly *magnetic.*

Form: crystals comparatively rare, rhombohedral. Usually massive, often as a black sand.

Occurrence: Vast beds occur in the Province of Quebec, in Virginia, and in Florida, but the chief commercial production is in India and Norway. Huge crystals are found at Kragerö, Norway.

Uses: Owing to its infusibility it is employed for lining puddling furnaces; also used in making ferrotitanium. It is not used as an iron ore owing to the difficulty of extracting the iron.

Other Titanium Minerals: *Titaniferous magnetite* abounds in many

localities, notably in the Adirondack Mountains, New York. It is not yet used.

Titanite is a calcium silicate containing titanium, $CaTiSiO_5$. It is rather widely distributed in many rocks in small *monoclinic crystals,* usually of brown *color,* though many other colors are found. The most notable occurrences from a mineralogical standpoint were the large brown crystals of Canada, figure 214, and the beautiful yellow, gem crystals of Tilly Foster Mine, New York and of the Alps.

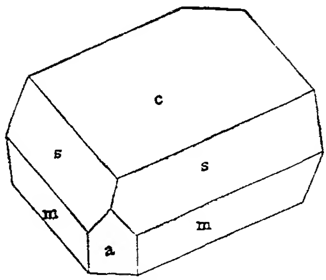


Figure 214. Titanite, Canada, Common Form

Brookite and **Octahedrite,** both have the same composition as rutile, TiO_2, but differ from it greatly in form.

Brookite occurs at Magnet Cove, Arkansas in stout *orthorhombic* crystals of black *color* and brilliant metallic *luster,* very different from the brown tabular crystals of the Alps. The Arkansas crystals are frequently more or less completely changed to rutile, which, while retaining the external form of brookite, shows itself as minute crystals with its own characteristics.

Octahedrite is usually in small, *tetragonal,* elongated double pyramids, though sometimes tabular. Several Swiss localities yield excellent specimens, but, like brookite, it is a rare mineral.

There are at least forty other minerals in which titanium occurs as an essential constituent, but all of them are rare.

TUNGSTEN MINERALS

Metallic tungsten is not found native and is a comparatively rare element. Nevertheless, its commercial uses are of such transcendent importance that every mineral collector should learn to recognize its chief ores, *wolframite, huebnerite* and *scheelite,* and know something about the metal and its unique properties.

Tungsten has the highest melting point of all the metals, 3350° centigrade, or to put it another way, it is the most difficultly fusible of all

metals. It is also exceedingly heavy, its density being 18.64, and very hard. In many respects tungsten is superior to steel. It never rusts and it is not attacked by acids. It is possible, though with very great difficulty, to draw it into very fine wire, and this is utilized for electric light filaments, hundreds of millions of which are used every year. As these filaments consume but 1.25 watts per candle power, while the old carbon filaments, which they have replaced, consumed 3.25 watts for the same degree of illumination, the savings amount to hundreds of millions of dollars every year.

High speed cutting tools contain 14 to 25 per cent of tungsten and have effected enormous savings in machine work. They retain their temper even when red hot and are said to save some 25 per cent of the power. Tungsten steel is used for armor plate and projectiles and the metal is alloyed also with other metals, adding greatly to their strength.

There are three closely related tungstates of iron and manganese: *Wolframite,* tungstate of iron and manganese $(Fe,Mn)WO_4$; *huebnerite,* tungstate of manganese, $MnWO_4$; and *ferberite,* tungstate of iron, $FeWO_4$. It will thus be seen that wolframite is a mixture, or "solid solution," of the other two.

Wolframite is the most abundant of these three minerals. It is characterized by its very high *specific gravity,* nearly 7.5, its easy *cleavage* in one direction, its black *color* and *streak,* sub-metallic *luster,* and by being *opaque.*

Huebnerite is distinguished from wolframite by never being perfectly black in *color,* but showing reddish-brown glimmerings when its masses are mostly black, while at times the whole mass is reddish-brown. It also has a brown or gray *streak,* never black. In its other properties it is quite similar to wolframite.

These two minerals differ in *crystallization,* though both are monoclinic. Wolframite has a very characteristic prismatic-tabular form, with chisel-edges on each side. The crystals are usually of large size. Huebnerite crystals, on the other hand, are generally bladed, small, striated and rarely well developed.

Ferberite is a much rarer mineral than the other tungstates and usually occurs in much smaller, black crystals.

Scheelite, calcium tungstate, $CaWO_4$, bears no resemblance to the three minerals just mentioned. It forms in tetragonal *crystals,* usually in double pyramids, either simple or modified slightly or sometimes much. Its *hardness* is 5, or slightly less; *specific gravity,* about 6.; *luster,* greasy-adamantine; *color,* usually pale yellow, but not infre-

quently white, greenish or deep orange; *streak,* white; commonly *subtranslucent,* though at times transparent. It usually shows pale blue *fluorescence* under ultra-violet rays.

Occurrence: All of these tungstates are commonly found associated with cassiterite, topaz, fluorite, apatite and quartz. Famous specimen localities are in Saxony and Bohemia, Portugal, New South Wales, Colorado. Commercial supplies are largely from China, Burma, Bolivia and the western United States.

URANIUM MINERALS

Uranium is one of the heaviest metals known, its *specific gravity* being 18.68. It has been used as a steel alloy, but owing to its high cost it cannot compete with other metals. Some of the uranium compounds have a limited use in medicine, in pottery and in making of yellow and also of iridescent glass. The importance of uranium ores, however, is due to the fact that they *always contain radium,* and are really of far greater value for the minute quantity of that excessively rare element which they contain, than for their uranium.

Uraninite is a mineral of very uncertain and variable composition. It always contains oxides of uranium and lead, and sometimes thorium, and small percentages of other elements.

Hardness: 5.5. *Specific gravity:* of pure crystals, 9 or over, of massive forms much less. *Color:* black. *Streak:* usually brownish-black. *Opaque.*

Form: *Crystals* are isometric, usually in cubes or octahedrons, or combinations of these forms. Usually *massive,* and then called "pitchblende;" sometimes with a botryoidal surface.

Occurrence: Its most important localities are Belgian Congo, Canada, Czechoslovakia. American localities of importance are Mitchell County, North Carolina; Black Hawk, Colorado and Portland, Connecticut.

Alterations: As a result of the alteration of uraninite, many minerals have been formed, at least a dozen new species having been discovered in Belgian Congo. These usually have beautiful bright green, yellow or orange colors. When in good crystals they are charming under the microscope. Orange colored *gummite,* canary-yellow *uranophane,* and other minerals result from its alteration in North Carolina and elsewhere.

Uses: It is an ore of both uranium and radium.

Carnotite, a canary-yellow powder disseminated through sandstone or less frequently in compact masses, is an important ore of both uranium and vanadium, found most abundantly in Colorado and Utah.

Other Uranium Minerals occur in considerable numbers, but are quite rare.

VANADIUM MINERALS

Vanadium presents a striking illustration of the value of chemical research coupled with efficient prospecting. In 1906 the consumption of vanadium in the United States was about 750 pounds, in 1930 it was about 1,800,000 pounds, with an additional 800,000 pounds used in foreign countries. This tremendous increase is due to the beneficial effect of adding it to steel. The automobile and railway industries are the chief consumers. Vanadium is also used in pharmacy, photography, dyeing, rubber, glass and many other industries.

The chief ores of vanadium are *patronite, descloizite, vanadinite* and *roscoelite.*

Patronite is a black, amorphous vanadium sulphide, VS_4, extensively mined in Peru, but not known elsewhere.

Descloizite is a vanadate of lead and zinc, $4(Pb,Zn)O.V_2O_5.H_2O$. *Hardness:* 3.5. *Specific gravity:* about 6.0. *Tenacity:* brittle. *Color:* usually dark brown to black, but sometimes red, yellow, gray. *Luster:* greasy. *Streak:* orange to gray. *Transparent* to opaque.

Form: usually crystallized in orthorhombic double pyramids, or drusy through close grouping of multitudes of tabular crystals.

Occurrence: Until a few years ago it was regarded as a rare mineral; now there are important mines in South West Africa, and elsewhere, in which it is the principal ore. Magnificent specimens are found. It is also mined in Northern Rhodesia. American localities are chiefly in New Mexico and Arizona.

Vanadinite is a compound of lead chloride and lead vanadate, $(PbCl)Pb_4V_3O_{12}$. This is one of the most spectacularly beautiful of minerals, especially when in minute crystals viewed under the microscope.

Hardness: 3. *Specific gravity:* about 6.8. *Tenacity:* brittle. *Luster:* vitreous to resinous.

Color: gorgeous aurora to orange-red grading into yellow and brown. *Streak:* yellowish-white.

Transparent to opaque.

Form: hexagonal; usually in hexagonal prisms, often modified by pyramids.

Occurrence: Many localities in Arizona and New Mexico produce magnificent specimens. Crystals up to five inches long come from South West Africa.

Roscoelite is a vanadium-bearing mica, mined in considerable quantities in Colorado, where it occurs in soft, greenish or brown scales in sandstone.

ZINC MINERALS

Zinc is a metal of much economic importance, whose average annual production in the United States amounts to some 500,000 tons. It is a bluish-white metal with a *specific gravity* in the neighborhood of 7. Cast zinc is hard and brittle, but when heated it becomes malleable and can be rolled into thin sheets, which have many uses, as for roofing-gutters, boiler plates and battery cells. When alloyed with copper it forms brass, one of the most useful of all alloys. Iron sheets or wire are protected from rusting by dipping them in melted zinc which "galvanizes" them. Zinc oxide, known to artists as "Chinese white" is in large demand not only as a paint, but it is also more largely used as a filler, especially for rubber goods, about 55 per cent of the weight of automobile tires being due to zinc oxide.

There are some fifty minerals of which zinc is an essential part, but only a few of them are important ores. These are *sphalerite, smithsonite, calamine, franklinite* and *willemite.*

Sphalerite, or "zinc blende," zinc sulphide, ZnS, is the most abundant zinc ore and quite a common mineral.

Hardness: 3.5 to 4. *Specific gravity:* about 4.0. *Tenacity:* brittle. *Fracture:* conchoidal.

Cleavage: dodecahedral and remarkably perfect, see figure 108.

Luster: usually resinous, sometimes adamantine. *Transparent* to translucent.

Streak: pale brown or yellowish, to nearly white.

Color: very variable. The purest varieties, free from iron, are nearly colorless; those containing much iron are black. Between these extremes may be found brown, yellow, green and red. Brown is the commonest color.

Phosphorescence: some varieties show *triboluminescence*, or the rare property of emitting light when scratched or rubbed; others are *fluorescent* and emit light during exposure to ultra-violet rays. These are usually also *phosphorescent*, the light continuing after the exposure ceases.

Form: Isometric crystals are common. They are usually very complex, often being rounded or deeply striated (by twinning). Granular forms abound, also cleavable masses.

Occurrence: It is a very common constituent of metalliferous veins, often associated with galena, chalcopyrite, barite, siderite, fluorite and

quartz. It is often the host of many rare elements such as gallium. indium and cadmium, as well as the commoner metals, iron, tin, mercury.

Among its most important occurrences are the many mines in the Missouri-Oklahoma district. Magnificent cleavable specimens come from Santander. Spain and from Cananea. Mexico.

Use: the most important zinc ore.

Name: its name means "treacherous." There is no other mineral whose appearance varies so much and which is at times so difficult to recognize at sight. The German miners called it blende. which means deceptive, because it resembled galena, but yielded no lead.

Distinguished by its dodecahedral cleavage. the angle between adjoining faces being 120°. Perfect cleavage dodecahedrons are rare. Also distinguished by its very characteristic resinous luster.

Sphalerite is a mineral with which every beginner should endeavor to familiarize himself. as it abounds in a great many localities all over the world and is a mineral of such varied aspects that a suite of specimens is of unusual interest.

Smithsonite, zinc carbonate, $ZnCO_3$. usually occurs in large *mammillary* masses, white, or not infrequently of bright. showy *colors*, such as blue, green or yellow; also brown or gray. *Streak* is white. even of the colored varieties. Its *hardness* is 5; *specific gravity:* about 4.4.

It is usually found in the upper levels of mines where it has been formed by the action of carbonated waters on sphalerite. Laurium in Greece, and Kelly, New Mexico, have produced beautiful material. some of it fit to cut into gems. Tsumeb. South West Africa and Broken Hill, New South Wales are notable for their crystallized specimens, producing attractive groups of small scalenohedrons. To what system do they belong? See page 55.

The name smithsonite was given to honor the philanthropist. James Smithson, the founder of the great Smithsonian Institution in Washington. in which are the great mineral collections of the United States National Museum.

Calamine, also called *hemimorphite,* is a zinc silicate with water. chemically combined. $H_2Zn_2SiO_5$.

Hardness: 4.5 to 5. *Specific gravity:* about 3.45.

The mineral varies greatly in appearance. The common ore is apt to be nearly massive. perhaps more or less cellular. or. it may be drusy, and of brown color, but when examined carefully the glassy *luster* of the *colorless* mineral will be seen. It is often more or less radiated in *structure,* and when crystallized the individual. tabular crystals fre-

quently occur in densely-grouped, crested or cockscomb-like forms, very characteristic of the mineral. The most notable specimens of this kind were found many years ago at Ogdensburg, New Jersey. The *crystals* belong to the orthorhombic system and are peculiar in having different shapes at the two ends.

Use: It is an important and abundant zinc ore.

Franklinite is an oxide of iron, zinc and manganese, $(Fe,Zn,Mn)O.(Fe,Mn)_2O_3$. This complex formula introduces the beginner to one of the interesting ways by which minerals are formed. Notice that zinc (Zn) occurs only in the first part of the formula, while iron (Fe) and manganese (Mn) occur in both parts. This is because oxygen forms only one compound with zinc, namely ZnO, while it forms two with both iron and manganese, namely FeO and Fe_2O_3, and MnO and Mn_2O_3. These two compounds of iron and manganese with oxygen are united with the one compound of zinc with oxygen to form the mineral franklinite. Magnetite is a union of nothing but the two iron oxides. The commas in the formula of franklinite show that the amount of zinc and manganese present varies, but these elements are essential parts of its make-up. If Zn and Mn were entirely absent the mineral would be magnetite. It is proper, therefore, to think of franklinite as magnetite with parts of its two iron oxides replaced by manganese oxides and part of its FeO replaced by ZnO.

Crystal form: The close relation between franklinite and magnetite would lead us to expect a similarity in crystal form, and that is what we actually find. Each of the minerals belongs in the isometric system, the octahedron being the common form, with the dodecahedron often present as shown in figure 215. The cube, which is so common a form in many other minerals is very rare in franklinite, as it is in magnetite.

Hardness: 5.5 to 6.5, the same as magnetite. *Specific gravity:* about 5.2.

Cleavage: It has no true cleavage, but an octahedral "parting" which resembles cleavage. *Fracture:* conchoidal to uneven. *Tenacity:* brittle.

Luster: usually metallic, sometimes dull. *Streak:* usually brown thus distinguishing it from magnetite, but it may be black, the same as magnetite.

Color: always iron-black, the same as magnetite. *Opaque.*

Slightly magnetic, while magnetite is always strongly magnetic.

Occurrence: With the exception of two insignificant occurrences in Germany, the only region in which franklinite is found is in Sussex County, New Jersey. Here are located the greatest zinc mines in the United States, those of the New Jersey Zinc Company at Franklin and

Ogdensburg, about fifty miles Northwest of New York City. The commonest type of "franklin ore" is a coarse-granular mixture of franklinite and willemite. Many other minerals are, at times, found in these mines, which are among the most prolific in mineral species of any in the world. Franklinite is often embedded in or scattered through white calcite in small, usually more or less rounded crystals or grains.

Figure 215. Franklinite Crystal, Franklin, New Jersey

Uses: Franklinite, after crushing and sizing, is separated from the other Franklin ores by the magnetic separator, and, in a finely crushed state, is mixed with fine anthracite coal and ignited. Metallic zinc is thus produced which is vaporized, reoxidized and cooled, thus producing the pigment, "zinc white." By smelting the slag, a product known as "spiegeleisen," an iron-manganese alloy, is produced, which is of great importance in steel manufacture.

Willemite, zinc silicate, Zn_2SiO_4, one of the richest of zinc ores, is found in enormous quantities at Franklin, New Jersey, associated with franklinite, but, unlike it, occurs plentifully in many other sections.

Hardness: 5 to 6. *Specific gravity:* about 4.1. *Tenacity:* brittle. *Cleavage:* basal.

Fracture: uneven. *Luster:* greasy to vitreous. *Transparent to opaque. Streak:* nearly white.

Color: very variable. Small crystals are usually colorless or pale green; large, coarse crystals, rich in manganese, are called *troostite,* and are brownish-red to gray; the more massive, granular, or radiated types are white, black, brown, yellow, red, green.

Crystal form: hexagonal, sometimes in elongated prisms, also in short, stout prisms.

Form: usually coarse-granular, or massive; less commonly, in cleavable masses, or radiated.

Occurrence: Franklin and Ogdensburg are by far the most important localities, but it is plentiful in Northern Rhodesia, Belgium, Germany and elsewhere.

Fluorescence: By far the most interesting property of willemite is its beautiful fluorescence under ultra-violet rays, see page 113. The color of the fluorescence is green regardless of the original color of the mineral, though the shade and the intensity vary. The black and dark-brown types are not responsive. A few of the lighter varieties of willemite not only fluoresce, but also *phosphoresce,* the light lingering after the rays which produce it have been shut off.

Zincite, "red oxide of zinc," is ZnO. Its most distinguishing character is its deep, rich-red to orange *color* and orange-yellow *streak.* It is usually *granular-massive,* or lamellar and *subtranslucent.*

Hardness: 4 to 4.5. *Specific gravity:* about 5.5.

Though it has been recorded from several localities, none but Franklin-Ogdensburg, New Jersey produces it in quantity. During the world war it was in large demand for radio detectors.

ZIRCONIUM MINERALS

Metallic zirconium is not found native. It is ranked as a rare metal and has but few uses, most important of which is in alloys. The oxide, ZrO_2, however, has such a very high melting point (3000°C) that its use for refractory bricks has become well established.

The chief ores of zirconium are the so-called *"Zircon favas,"* or *baddeleyite* of Brazil and the mineral *zircon.*

Zircon, zirconium silicate, $ZrSiO_4$, occurs in tetragonal *crystals,* usually combinations of prisms and pyramids, as shown in figures 216–218

Hardness: 7.5, hard. *Specific gravity:* averaging about 4.7.

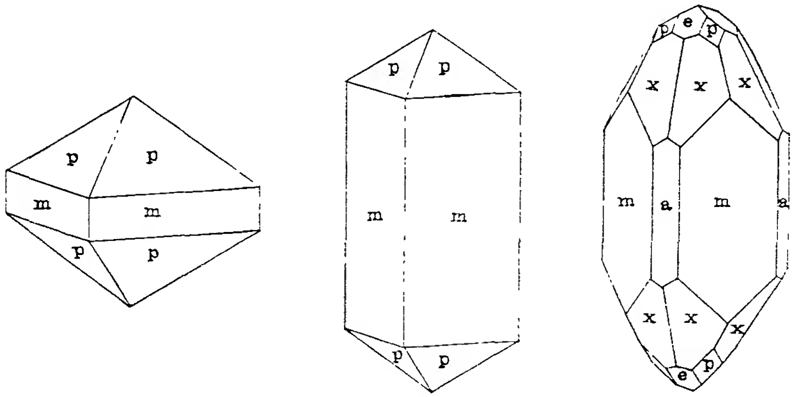
Luster: adamantine, brilliant. *Streak:* uncolored.

Color: commonly a reddish-brown or gray, but also, not infrequently, yellow, red or colorless, rarely blue or green.

Transparent to opaque.

Occurrence: It is very widely distributed, though in small quantities, as a nonessential part of rocks of many kinds. In a few places it is quite abundant, notably in North Carolina, while in Florida, India and elsewhere it is found as a beach sand, often in minute crystals of much beauty and perfection. In Ceylon and France it occurs in red crystals

(*"hyacinth"*) yielding choice gems; it is also found in the gold-bearing sands of Australia and elsewhere. Gems of great beauty and many colors have been cut from zircons found in Ceylon, India, Siam and other countries. The artificially colored, sky-blue gems (*"starlite"*) of Siam are exceptionally attractive. Zircon gems have a beautiful play of colors, due to their high index of refraction, and when colorless much resemble the diamond.



Figures 216–218. Common Forms of Zircon Crystals

B. ROCK-FORMING MINERALS

It is remarkable that two of the chemical elements, oxygen and silicon, constitute more than half of the outer crust of the earth and that nearly 99 per cent is made up of only twelve elements. Of these twelve but two, carbon and sulphur, are found as elements in nature. The compounds of the twelve elements are numerous, but after all, the number of really common minerals which form the rock types is comparatively small. The variations from these types are innumerable and embrace all minerals, but the beginner is concerned with those only which he is likely to meet or which are of importance. Quite a number of these have already been treated because of their metallic content. It remains, therefore, to consider a few minerals of major importance chiefly as rock-formers, and a few others which have no metallic importance, but with which, for one reason or another, the beginner should become acquainted.

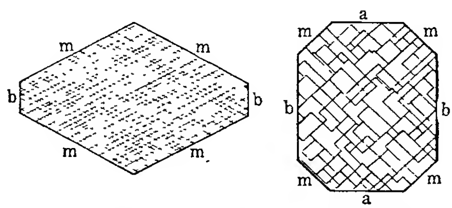
AMPHIBOLE AND PYROXENE GROUPS

The amphiboles and pyroxenes are closely related and very abundant rock-forming silicates. If they are judged by ordinary rock occurrences they are apt to be regarded as about the least attractive and the most puzzling of all minerals. Typical specimens, however, add quite a little

to a mineral collection and there are interesting points to be learned about them.

Differences: It is often very difficult, or even impossible, for the beginner to distinguish between amphibole and pyroxene in rocks of the more massive types. If crystals of both are compared, they are easily distinguished, and when once the differences between them are clearly recognized, the eye will quickly detect these differences even in quite inferior material, especially if aided by a pocket magnifier.

Both are *monoclinic* and occur in *prismatic crystals,* but *the angles between the prism faces are very different.* In amphibole this angle is about 124½°, or nearly that of the regular hexagonal prism (120°), while in pyroxene it is about 93°, or nearly that of a right angle or square prism. If, therefore, a crystal shows a square development, it is safe to conclude that it is not amphibole. There may be other faces, *a* and *b,* between the prisms, *m,* of the pyroxene, which give it an eight-sided, instead of a four-sided, appearance and amphibole crystals may have other faces, but they never appear square. The differences are made plain in figures 219 and 220, which show how the crystals, if held



Figures 219, 220. Differences between Amphibole and Pyroxene

with their prisms vertical, appear when looked down upon from above. In each case *m* is the prism.

Cleavage: Both minerals have *cleavage parallel to the prism faces* just mentioned. It is easy and very common in amphibole and rarer in pyroxene. Pyroxene also frequently shows a "parting," or pseudo-cleavage, parallel with the base, which may be noted not only in actual breaks, but also in lines on the prism parallel with the base, as shown in figure 228. You will, of course, much more frequently meet these minerals in crystalline masses than in distinct crystals. If, therefore, you remember that the cleavage is parallel with the prism faces and consequently that its angles will be the same as in crystals, you will often be able to recognize these minerals in the field when collectors who have not studied these differences will not know which mineral they have found.

Fibrous Forms: Amphibole frequently occurs in fibrous forms, while pyroxene almost never is fibrous.

Occurrence: Both minerals occur in volcanic and eruptive rocks; but pyroxene is commoner than amphibole in basalt and diabase, while amphibole is commoner in granite. Amphibole is the commoner mineral of the two in gneiss and especially in the schists. Both occur in limestones.

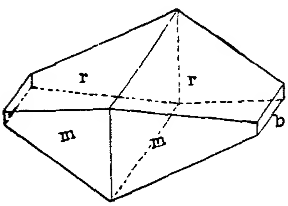
AMPHIBOLES

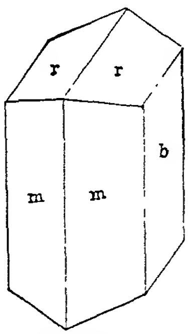
AMPHIBOLE is one of the commonest of the rock-forming minerals and occurs in many forms, which the beginner will often meet in the field, and with which it is, therefore, important for him to become familiar. As many of the varieties grade from one into another, it is wiser to learn of them from thoroughly typical specimens bought from reliable dealers. The most important of these varieties are *tremolite, actinolite, asbestus, nephrite,* and *hornblende,* the last named being much the most common.

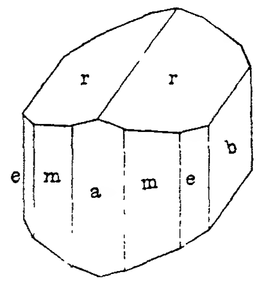
Composition: a complex silicate, always containing magnesium, usually calcium and frequently iron, while many analyses show manganese and smaller quantities of many other metals. The composition is very similar to that of pyroxene.

Hardness: 5 to 6. *Specific gravity:* 2.9 to 3.4.

Form: monoclinic, figures 51, 221–224. *Cleavage:* prismatic, angle 124½°; see page 80.







Figures 221–223. Common Forms of Amphibole Crystals

Luster: vitreous, pearly or silky, according to the variety.

Color: usually black, green or gray.

Streak: usually uncolored, or paler than the color.

Opaque, subtranslucent or sometimes transparent.

Tremolite is a silicate of calcium and magnesium, $CaMg_3(SiO_3)_4$. It is usually bladed, of white or gray color, though the beautiful variety, *hexagonite*, from Edwards, New York, is lavender. It breaks readily into splinters, often with sharp points, which stick in the fingers. For

its other properties see amphibole above. Well-known localities are Gouverneur, New York and Lee, Massachusetts.

Actinolite is a silicate of calcium, magnesium and iron, $Ca(Mg,Fe)_3(SiO_3)_4$. It is usually columnar or bladed, the blades either lying singly in masses of talc-schist, or some other schist, or aggregated into confused masses. Color is commonly bright green or grayish-green. It grades from nearly opaque to nearly transparent.

Figure 224. Amphibole, variety Hornblende, Crystals in Quartz, Cumberland, Rhode Island

Asbestus is a fine-fibrous variety of amphibole, but commercial "asbestos" is largely serpentine. The fibers are sometimes eighteen inches or more in length.

Nephrite is a compact and exceedingly tough variety, often called *jade*, though this term includes other minerals, chiefly jadeite. Its best known occurrence is in New Zealand, where it is called "green stone."

Hornblende is a complex silicate of calcium and magnesium with aluminum and iron, very similar to augite. It is very common as a part of many granites, basalts and schists. It is usually opaque and black In volcanic rocks its crystals are ordinarily short and stout prisms, but in schists it is often bladed or fibrous. Its properties are given above under

amphibole. Black tourmaline often resembles hornblende, but it can be distinguished by its lack of cleavage, which is well-marked in hornblende.

MONOCLINIC PYROXENES

PYROXENE is one of the commonest of the rock-forming minerals, and as its identification is often difficult, it is well for the beginner to secure by purchase thoroughly typical specimens of its two commonest varieties, *diopside* and *augite.* By so doing he will be able to recognize it in the field, where he will be almost sure to meet it in rather obscure form.

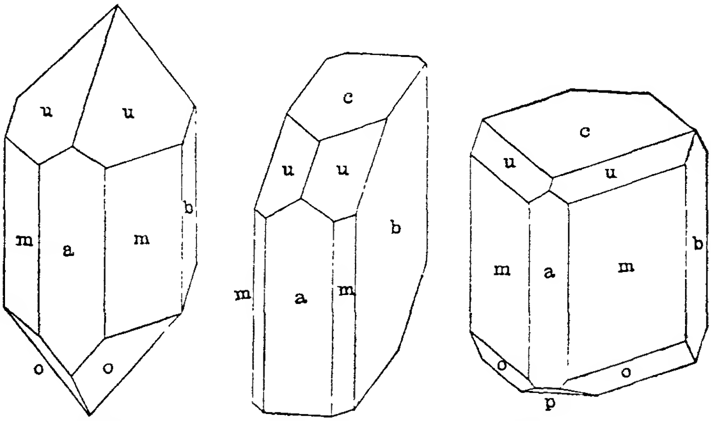
Composition: a complex silicate, always containing magnesium and calcium, frequently iron and sometimes manganese and smaller quantities of other metals. The composition is very similar to amphibole.

Hardness: 5 to 6. *Specific gravity:* 3.2 to 3.6.

Form: monoclinic; see figures 52, 225–227.

Cleavage: prismatic, angle 93°, see page 80.

Parting: parallel to base, *c*, often prominent, figure 228, see page 214.



Figures 225–227. Common Forms of Pyroxene Crystals

Luster: vitreous, resinous or dull.

Color: usually black, dark green to grayish-green, sometimes brown or white.

Streak: white to grayish-green.

Opaque: usually; sometimes transparent.

Occurrence and means of distinguishing it from amphibole are given on pages 214, 215.

Diopside is a silicate of calcium and magnesium, $CaMg(SiO_3)_2$. It is far less common than augite, being usually found in the crystalline

limestones and but rarely in granites and related rocks and almost never in volcanic rocks. It is usually light-colored, white, grayish or light green, rarely dark green. One of its commonest forms is shown in figure 227, but it is often in slender prisms. Its properties are given above. *Transparent crystals,* yielding fine gems, occur at DeKalb, New York, also in the Ala Valley, Italy.

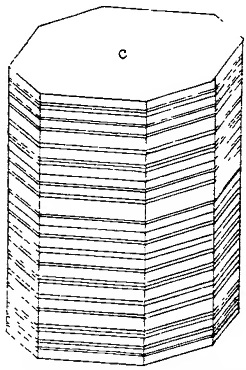


Figure 228. Pyroxene Crystal, Showing Parting

Augite is a complex silicate of calcium, magnesium, aluminum and iron, $CaMgSi_2O_6$ with $(Mg, Fe)(Al,Fe)_2SiO_6$. It is one of the commonest of the minerals which make up the eruptive rocks. It is usually opaque; black or very dark green. One of the commonest forms of its crystals, found in Bohemia, is shown in figure 52. It is usually short-prismatic or lamellar. Its properties are given above. See also page 214.

ORTHORHOMBIC PYROXENES

Enstatite, a silicate of magnesium, $MgSiO_3$. When pure, the *color* of this mineral is white or pale gray or greenish, but usually it contains iron and then its color is darker, passing from olive-green to brown. Its *luster* is pearly, but only markedly so in the dark, iron-bearing variety, called *bronzite,* because of its bronze-like sheen.

It is rarely found in orthorhombic *crystals;* usually it is in coarsely crystalline, lamellar masses. Its *hardness,* 5.5, and *specific gravity,* 3.2, are approximately the same as pyroxene. It is fused with very great difficulty and is, therefore, used as *number 6 in the "scale of fusibility."*

Enstatite is often a constituent of some of the igneous rocks, such as pyroxenite, peridotite, gabbro, and it is frequently found in serpentine, also in meteorites. Very pure, cleavable enstatite occurs in Norway, while fine bronzite comes from near Webster, North Carolina.

Hypersthene, a silicate of iron and magnesium, $(Fe,Mg)SiO_3$. As the percentage of iron in enstatite increases it passes into hypersthene.

Its luster is somewhat pearly and in the mineral from the labradorite locality in Labrador it has a beautiful metallic sheen, due to multitudes of minute crystals, in parallel position, enclosed in it. It is slightly *harder,* 5 to 6, and *heavier, specific gravity* 3.4 to 3.5, than enstatite, and has a good prismatic *cleavage.* It is usually in foliated masses, but occasionally is found in broad cleavage plates.

It is an ingredient of the igneous rocks, *norite* and *gabbro* and is also found in trachyte and andesite.

Epidote is a silicate of aluminum, iron and calcium, with water, $HCa_2(Al,Fe)_3Si_3O_{13}$.

Hardness: 6 to 7. *Specific gravity:* 3.2 to 3.5. *Monoclinic;* figure 229 shows a common form.

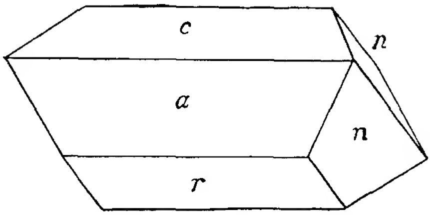


Figure 229. Epidote, a Common Form of Crystal

Specimens from different localities often show wide differences in form and color, but as a general rule the massive mineral has a peculiar and characteristic yellowish-green (pistachio) *color,* not common in other minerals, which makes the beginner's guess as to its identity come true. The finest *crystals* were found many years ago in Austria and are groups of slender, prismatic crystals, black and highly lustrous by reflected light, but green or brown by transmitted light. Magnificent specimens are also found near Sulzer, Alaska, in stout, prismatic crystals, nearly black. While it is not at all likely that the beginner will find such superb crystals, it is well for him to familiarize himself with them when he visits the great museums, as someone did discover them some time and it may be that he will come across something even better. Massive epidote of the pistachio-green color is a common mineral in granites, gneiss and other crystalline rocks. *Unakite* is the name given to an attractive rock consisting of epidote, red feldspar and quartz,

found abundantly in Virginia and North Carolina. It has been cut into showy cabochon stones.

FELDSPARS

FELDSPAR is not the name of any one mineral, but of the commonest group of the rock-forming minerals. Geologically, the feldspars are also the most important of all minerals, being found as a necessary part of a great many of the commonest of rocks. It is very desirable, therefore, that the beginner become acquainted with them. Their chief characteristics are:

Crystals: monoclinic or triclinic. The angles between adjoining prism faces vary but slightly from 60° and 120°.

Cleavage: easy in two directions at right angles to each other, or nearly so.

Hardness: usually 6, or near to 6.

Specific gravity: usually between 2.5 and 2.75.

Color: white or some pale shade of pink, red, yellow or gray, less commonly green or brown or some dark color.

Luster: vitreous to pearly.

Streak: always white or uncolored.

Distinguished from quartz by their inferior hardness and distinct cleavage; from calcite by their greater hardness, the very different angle of cleavage and by not effervescing (bubbling) in acids. It is always well to check up on more than one characteristic, for feldspars are frequently altered or in process of alteration to clay (kaolinite), and they are then soft, but the acid test will settle the question of whether the mineral is calcite or not.

Composition: All of the common feldspars are silicates of aluminum and one or more other metals, either potassium, sodium or calcium. There are three types:

Potassium feldspar, including **orthoclase** and **microcline,** whose formula is $KAlSi_3O_8$.

Sodium feldspar, albite, whose formula is $NaAlSi_3O_8$, conveniently abbreviated to Ab.

Calcium feldspar, anorthite, whose formula is $CaAl_2Si_2O_8$, abbreviated to An.

All of the other feldspars (except a few rare species) are made up of two or more of these fundamental types. Their separation from one another is a problem to which advanced mineralogists have given much study, but does not concern the beginner, for to be absolutely sure of the identity of a particular piece of feldspar it is necessary to know its

chemical composition exactly and its optical properties, as determined by the petrographic microscope. It is customary, however, in field work, to disregard the fine distinctions between the various feldspars and to trust to sight determinations.

Orthoclase and **Microcline,** common feldspar.

Orthoclase has long been the name assigned to the common feldspar of granite, pegmatite, gneiss and many other similar rocks. From a technical standpoint this is not usually correct, for the feldspar which occurs in large masses in pegmatite is usually *microcline.* The error is so deep-rooted, even among teachers of mineralogy, and in all text-books, that the beginner will constantly hear the name orthoclase used instead of microcline. The present generation can do mineralogy a real service by refusing to perpetuate this error. Orthoclase, however, is a common feldspar, for it is abundant, as the variety *sanidine,* in the eruptive rocks, rhyolite (page 258), trachyte (page 258) and others, while the feldspar crystals of many porphyries (page 258) are orthoclase.

Orthoclase and microcline have the same *composition* being silicates of aluminum and potassium, $KAlSi_3O_8$.

Form: Orthoclase is monoclinic; microcline is triclinic; but they are so nearly alike that the beginner may regard them as identical. Crystals are common, both simple, figures 50 and 230, and twins, figures 231, 232.

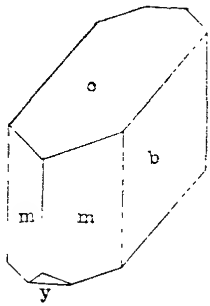


Figure 230. Orthoclase, a Common Form of Crystal

Hardness: 6. to 6.5. *Specific gravity:* 2.54 to 2.58.

Cleavage: easy in two directions, figure 111, in orthoclase, at 90°, in microcline so near 90° that the variation is not perceptible to the eye.

Fracture: uneven in the remaining direction of cleavage masses. In glassy crystals it may be conchoidal.

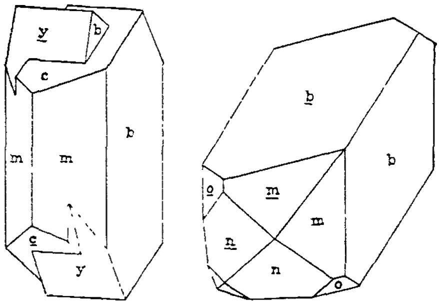
Tenacity: brittle, but not excessively so.

Luster: vitreous or pearly.

Color: usually white, flesh-color to brick-red, yellow or gray. *Amazonstone* is a green or greenish-blue variety of microcline.

Streak: uncolored. *Transparent* to translucent.

Occurrence: Common feldspar often occurs in large, cleavable masses in pegmatite veins or dikes. The glassy variety of orthoclase, *sanidine*, is common in the eruptive rocks, as in the trachyte of the Drachenfels, Germany. Splendid crystals of orthoclase occur at Baveno, Italy, also



Figures 231, 232. "Carlsbad" and "Baveno" Twins of Orthoclase

in the Eastern Alps (the variety *adularia*); at many localities in the Rocky Mountains and scores of other localities. The most notable occurrence of crystals of microcline is the Pike's Peak region in Colorado, where fine flesh-color crystals are found as well as magnificent crystals and groups of *amazonstone.* Fine, large cleavages of amazonstone occur abundantly at Amelia Court House, Virginia and in Madagascar. Cleavable microcline is very abundant at Bedford, New York, in Delaware County, Pennsylvania, Maine, Canada, North Carolina, South Dakota and many other localities.

Uses: Both orthoclase and microcline are used extensively in the pottery and glass industries and also have many other applications in the arts. Amazonstone and the clear yellow orthoclase of Madagascar are used as gems.

THE PLAGIOCLASE FELDSPARS include **albite** and **anorthite,** and four other feldspars which are intermediate between them, namely **oligoclase, andesine, labradorite** and **bytownite.** The only plagioclase feldspars which the beginner is likely to meet in the field are albite, oligoclase and labradorite.

Plagioclase is from two Greek words *plagios,* meaning oblique, and *klasis,* fracture. This at once suggests that in this group of feldspars the two *cleavages are not at right angles* as in orthoclase, but inclined to each other. This is actually true, but the variation from the right angle is slight. The advanced mineralogist is able, by the aid of expensive

instruments, to distinguish between the feldspars by measuring these slight variations, but the beginner cannot positively identify them, though he can usually make good guesses.

A prominent, though not universal, characteristic of the plagioclase feldspars is the *striations* which may be seen on the most prominent cleavage. These were mentioned on page 75 as due to twinning. If you find a feldspar with these striations you can be sure that it is not orthoclase and that it is a plagioclase.

Albite (from the Latin *albus,* white), soda feldspar, is, typically a snow-white plagioclase feldspar; sometimes it is grayish, greenish or reddish.

Composition: silicate of aluminum and sodium, $NaAlSi_3O_8$.

In most of its other properties it conforms to the feldspar group as described on page 220.

Twinning is so prominent a characteristic that the name *"albite twinning"* has been given to its commonest type, which manifests itself usually in the striations noted above. These generally show as fine parallel lines, but sometimes, as in the albite from Amelia Court House, Virginia, the twinning is coarse, a mass being made up of many tabular crystals and thus appearing coarsely laminated.

Common varieties of albite include masses not distinctly twinned but made up of layers (*cleavelandite*), often curved; also granular forms. *Moonstone* (see page 117) is often albite.

Occurrence: Albite is a very common mineral, being found as a constituent of many granites, pegmatites, gneiss and other rocks. Crystals of much beauty abound in the Alps, in Norway, and hundreds of localities all over the world. At Amelia Court House, Virginia groups of tabular crystals up to ten or twelve inches occur, as also a cleavable, delicate-blue moonstone. Gorgeous cleavages of moonstone *peristerite* occur at Hybla, Ontario.

Uses: Potters prefer albite to other plagioclases and to orthoclase in making their wares, owing to its fusing more easily. Moonstone, if of gem quality, is cut into semi-precious stones, but most moonstone, including that of Ceylon, is another rarer feldspar (anorthoclase).

Anorthite, calcium feldspar, silicate of aluminum and calcium, $CaAl_2Si_2O_8$, is a comparatively rare plagioclase feldspar, occurring most commonly in the volcanic rocks such as basalt, diorite, and norite. Glassy crystals are found at Vesuvius and similarly in Japan where they are thinly coated with the black lava.

Labradorite, "labrador spar," a silicate of aluminum with both calcium and sodium, is usually a *dark gray* plagioclase feldspar. Its most

typical occurrence is on a small island off the coast of Labrador. Here it is found plentifully in pure *cleavable masses* which exhibit a marvellously *gorgeous change of colors,* deep blue usually predominating, with green, yellow and coppery-red less frequently seen. Great mountains largely composed of labradorite occur as the rock anorthosite in the Adirondack Mountains, New York. The dolerite porphyries of Cape Ann and Marshfield, Massachusetts (figure 255, page 259), show multitudes of labradorite crystals scattered through the dark groundmass of the rock. Labradorite is used to some extent as a gem and has been manufactured into table tops, paper weights and many ornamental objects.

Oligoclase is another plagioclase feldspar, a silicate of aluminum with sodium and calcium, but nearer to albite than is labradorite and usually of lighter colors. It often very strikingly *shows the striations,* due to repeated twinning, which characterize the plagioclase group. Its most attractive occurrence is at Tvedestrand, Norway where the variety *sunstone* is found in red, cleavable masses exhibiting a charming golden sparkle, "schiller," due to the reflection of light from minute tabular crystals of hematite or goethite, in parallel position, enclosed in the feldspar. Examined with a lens or under the microscope, sunstone is a gloriously beautiful mineral. *Moonstone*-oligoclase occurs in Delaware County, Pennsylvania, while in Mitchell County, North Carolina there is a colorless, glassy variety. Ordinarily oligoclase is in excellent cleavages resembling albite or microcline.

FELDSPAR-LIKE MINERALS

This group embraces a few minerals more or less closely related to the feldspar group, being silicates of aluminum with potassium, sodium and calcium.

Nephelite, typically, is a silicate of sodium and aluminum, $NaAlSiO_4$. Its most prominent characteristic is its oily or *greasy luster.* Its *color is usually gray,* but brick-red, grayish-green and brown are not uncommon. It is usually massive, though sometimes found in hexagonal crystals, either large and coarse, as in Renfrew County, Ontario, or small, sharp and brilliant, as at Vesuvius.

Occurrence: Nephelite is important as a rock-forming mineral, there being very considerable deposits of nephelite-syenite in Norway, in Maine, Arkansas and elsewhere.

Sodalite, often associated with nephelite, is similar to it in composition except that chlorine is present. Its typical formula is: 3NaAl-

$SiO_4.NaCl$. It has a *vitreous luster,* and is often of a deep, rich *blue color,* though many other colors are noted. Bancroft, Ontario has produced much beautiful sodalite rock which has been sold, especially ir England, as "Princess Marble."

Cancrinite is similar to nephelite in composition with the addition of calcium carbonate and water. It is commonly associated with sodalite in nephelite-syenites and most commonly has a rich *yellow to orange color.* Litchfield, Maine, is a well known locality.

Lazurite is a *rich-blue* mineral related to nephelite but containing sodium sulphide. It is familiar to lovers of decorative and semi-precious stones in *lapis-lazuli,* which is a mixture of lazurite with various other minerals. Lapis-lazuli is highly prized by the Russians. It occurs in Persia and Chile.

Leucite is a postassium-aluminum silicate, $KAl(SiO_3)_2$. Typical crystals are *trapezohedrons,* figure 233, of white or gray *color,* vitreous *luster, hardness:* 5.5 to 6. They occur in lavas especially at Vesuvius and near Rome, Italy. At some places great rock masses are formed of leucite, as in the Leucite Hills of Wyoming. The Romans used leucite-lava for millstones. Potash was first discovered among minerals in leucite in 1796.

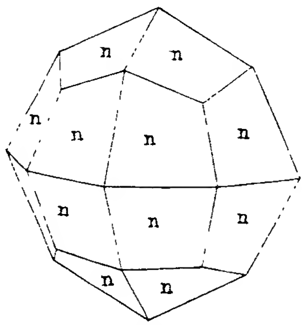
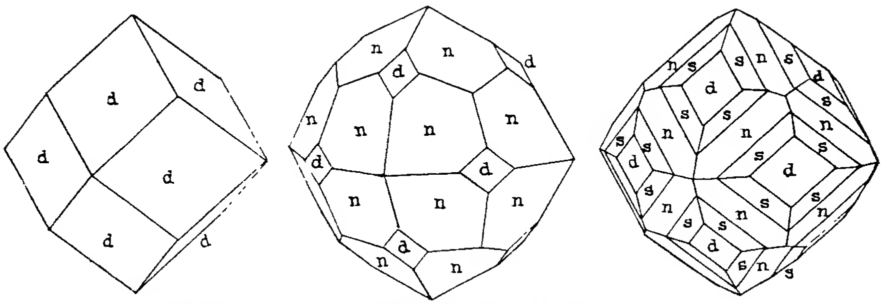


Figure 233. Leucite, Common Form

GARNET GROUP

Most people who have not studied minerals, think of garnet as a deep, rich red gem; indeed, the term "garnet-red" is frequently used to describe such a color. It is amazing to such people to learn that garnets of many and widely different colors occur and that garnet is not the name of one definite chemical compound but of a series of compounds which unite with each other to produce a great many varieties to which distinguishing names have been given.

All garnets are hard, *hardness* being 7. to 7.5. Their *luster* is vitreous. All garnets crystallize in the same class of *isometric* crystals, and cubical and octahedral crystals are notably rare, while dodecahedrons, figure 234, and trapezohedrons, figure 233, and combinations of these with other forms, figure 236, which are rare in most other species, are comparatively common in garnet. The beginner in the study of crystals will find garnet his greatest help in understanding certain forms and will be charmed by the many faces of gemmy little crystals of garnet which he may find or see in museums.



Figures 234—236. Common Forms of Garnet Crystals

The chemist, too, finds much delight in studying the composition of the garnet group. He finds that all of the varieties are similar silicates, but that the metallic elements vary greatly. This is clearly shown by writing the typical formulas of the chief varieties.

Grossularite	$Ca_3Al_2(SiO_4)_3$
Pyrope	$Mg_3Al_2(SiO_4)_3$
Almandite	$Fe_3Al_2(SiO_4)_3$
Spessartite	$Mn_3Al_2(SiO_4)_3$
Andradite	$Ca_3Fe_2(SiO_4)_3$
Uvarovite	$Ca_3Cr_2(SiO_4)_3$

Let us see how these varieties differ from each other in other ways than chemically.

Grossularite *varies greatly in color;* it is commonly colorless or white, as in Quebec; but it is occasionally green as in the so-called *"South African Jade,"* or pale yellow, as in the Siberian *viluite.* It is never a deep blood-red or ruby red. One quite distinct variety *rosolite* from Mexico, is rose-pink and *essonite* or *cinnamon-stone* has a brownish-red color. Essonite has been cut into handsome gems and the "South African Jade" has been made into many ornamental objects. *Specific gravity* is 3.42 to 3.72.

Pyrope, or *"precious garnet"* is the deep *blood-red* variety, most familiar in the garnet jewelry from Bohemia, where it occurs in serpentine. Little pebbles of pyrope are found in the ant hills of the Navajo Reservation, Arizona, and are collected by the Indians and sold for cutting into gems. Associated with them are pebbles of peridot, a variety of chrysolite or olivine, which suggests that the pyrope is derived from a rock called peridotite. This rock is the matrix of the diamonds of South Africa and pyrope is found there and is called "Cape ruby." *Specific gravity* is 3.7.

Almandite, or **almandine,** is probably the *commonest variety* of garnet, and the one most apt to be met in the field. It is usually of a red color nearly as deep as pyrope, but it also often has a purplish cast, especially in the almandine gems of the jewelry trade. One of the most notable occurrences is near Fort Wrangel, Alaska, where fine deep red crystals are found embedded in mica-schist. Crystals up to 14½ pounds in weight are found near Salida, Colorado, altered on the surface to a chlorite called aphrosiderite. Granite, gneiss and mica-schist, figure 237, are usually the mother-rocks of almandite. *Specific gravity* is about 4.25.

Figure 237. Garnet Crystals in Mica-Schist, Redding, Connecticut. Courtesy of J. G. Manchester

Spessartite is a rare variety of garnet. It always has *brown mixed with its red.* Some of the fine garnets of Delaware County, Pennsylvania are spessartite. At Amelia Court House, Virginia gem material of unrivaled beauty is found. Excellent spessartite for cutting also comes from Madagascar. *Specific gravity* is 4.18.

Andradite is one of the commonest kinds of garnet. Several distinct varieties are included under andradite so that there is a gradation from the nearly opaque, dark brown, common garnet through the *yellowish-brown polyadelphite,* of Franklin, New Jersey, and the brilliant little *yellow* crystals of *topazolite* of the Ala Valley, Italy, to the yellowish-green and deep *emerald-green demantoid* of the Ural Montains, which is highly prized as a gem and is sold as "Uralian emerald." Andradite also includes many other named varieties, the commonest of which is the *coal-black melanite,* of Franklin, New Jersey and Frascati, Italy. *Specific gravity* is about 3.85.

Uvarovite is very similar in color to the richest *emerald-green* demantoid. It is, however, very different in chemical composition, its color being attributed to the chromium which it contains. Uvarovite is very rare and is highly prized. The finest specimens come from the Ural Mountains. Orford, Quebec, is the best known locality in North America. It is almost always associated with chromite in serpentine, but occurs also in crystalline limestone. *Specific gravity* is about 3.5.

It will be seen from the above that there are so many and such varied kinds of garnet that quite an extensive collection could be gathered of nothing but this mineral. It is one of the many charms of mineral collecting to find specimens differing widely from each other in some respects, but all bound together by some fundamental characteristics into one great group.

MICA GROUP

The most important micas are *muscovite, biotite, phlogopite* and *lepidolite.*

How many of the hosts of people who have enjoyed the dazzling sparkle of mica on the Christmas tree, or in mica-bearing rocks, or who have split it into very thin leaves, know that *mica is not the name of a mineral,* but of a group of minerals? What have the different kinds of mica in common and how do they differ?

They all occur in *six-sided crystals* with angles practically the same as that of a regular hexagonal crystal, 120°, but really they belong to the *monoclinic system.*

The most prominent and best-known characteristic is their wonderful

basal *cleavage.* This is so highly developed that it is possible to split off sheets less than one five-hundredth of an inch in thickness. Mica is the best illustration of this cleavage, and therefore, it has been called *micaceous cleavage.* It is a great aid to their identification in rocks.

Another property which all the micas possess is the *elasticity* of the sheets. Notice how readily they can be bent and that when the pressure on them is released they spring back to their original position. Contrast this with flexibility described on page 37.

The micas are usually soft, *hardness* being 2. to 3 and, therefore, they are easily scratched with the finger nail, though lepidolite is harder.

Specific gravity: 2.7 to 3.1.

Luster: pearly on the base, vitreous on the side faces.

Percussion-figures: If a thin cleavage plate of any mica is struck a blow by a dull point, a six-rayed star is produced, whose lines are parallel to the sides of the crystal. This is called a "percussion-figure" Try it.

Muscovite, "isinglass" is a silicate of aluminum and potassium, with water entering into the compound. Formula is $H_2KAl_2(SiO_4)_3$.

Hardness: 2. to 2.5. *Specific gravity:* about 2.8.

Form: monoclinic, but crystals usually in six-sided plates, figure 238, sometimes several feet in diameter. Very common in scales scattered through rocks or gathered together into scaly, compact masses.

Figure 238 Muscovite Crystal, Henry, Lincoln County, North Carolina

Color: usually colorless, gray, light brown or green.

Streak: uncolored. *Transparent* to translucent.

Tenacity: tough, flexible, elastic.

Occurrence: Muscovite is the light-colored mica of granite, pegmatite, gneiss and mica-schist, but is rarely seen in volcanic rocks. Plates large enough to be of commercial value are found only in pegmatite. The best-known mines in the United States are in North Carolina, Virginia and South Dakota. The commercial supply comes chiefly from India.

Uses: Muscovite is used in almost countless ways. In sheets it is employed in the electrical industry, for glazing in stoves, for lamp

chimneys and in many other ways. For these purposes it must be clear, free from cracks and impurities and split easily into flat sheets. The great bulk of the production of American mines is not of good enough quality for these uses and is called "scrap mica." This is ground and used in the manufacture of roofing, rubber tires, wall paper, fancy paint, and as a lubricant. Large quantities are consumed as "snow" by the moving picture industry.

Biotite, "black mica," magnesium mica, is a complex silicate of aluminum, magnesium, iron and potassium, with a little water chemically combined. Its formula is quite impressive: $H_2K(Mg,Fe)_3Al(SiO_4)_3$.

Hardness: 2.5 to 3. *Specific gravity:* about 2.9.

Form: same as muscovite.

Color: usually black, less commonly brown or dark green.

Streak: uncolored.

Transparent to opaque.

Tenacity: tough, flexible, elastic, somewhat sectile. Weathering destroys all of these properties and makes it brittle.

Occurrence: *Biotite* is the dark-colored mica of granite, gneiss, mica-schist and the volcanic rocks. It is very common, but fine specimens are not often found. Probably the best crystals come from Vesuvius, the colors there often being much paler than in the large sheets found in Canada and elsewhere.

Uses: Biotite has no commercial uses.

Phlogopite, "amber mica," is a complex silicate of aluminum, magnesium and potassium with water. It differs from biotite chiefly in that it contains but little iron. Formula: $H_2KMg_3Al(SiO_4)_3$.

Color: yellowish-brown to brownish-red; rarely light green to almost white.

Asterism: Phlogopite often shows a star when viewed by transmitted light, figure 144, (see page 111).

Other properties are practically identical with biotite and the mica group in general.

Occurrence: It is commonly found in the crystalline limestones and in serpentine. Large plates and crystals of excellent quality are found abundantly in Canada. Franklin, N. J. yields attractive specimens.

Uses: "Amber mica" is the most highly prized of the micas for electrical uses.

Lepidolite, lithia mica, is a silicate of aluminum, potassium and lithium, but that is only part of its chemical make up, for it also contains chemically combined water and fluorine and sometimes the rare

metals rubidium and caesium. Even omitting these its formula is quite formidable: $KLi[Al(OH.F)_2]Al(SiO_3)_3$.

Color: usually lavender, but also "peach-blossom red," gray or yellow.

Form and *Occurrence:* Unlike the other micas, lepidolite rarely occurs in distinct plates showing cleavage, but is *usually in masses, made up of multitudes of scales.* Its name, indeed, is derived from the Greek, *lepis,* a scale. These scales are sometimes so minute as to give a piece, at first sight, the appearance of being without crystallization, but when examined with a lens the bright, *pearly luster* of the base of many crystals may be noted. Such is the material found abundantly with pink tourmaline in California. In Maine, lepidolite occurs in aggregates of much coarser crystalline grains and also in distinct six-sided crystals. Curved crystals are common. It is usually found in pegmatite often associated with the lighter-colored tourmalines, also with spodumene or other lithia-bearing minerals.

Hardness, at times as high as 4, thus exceeding that of all other micas, but it also runs as low as 2.5. *Specific gravity:* 2.8 to 3.3.

Uses: It is of no value as a mica, and its lithia content is not sufficient to give it value. Its easy fusibility to a clear glass has suggested its use in glass-making. Try melting it on the kitchen range.

CHRYSOLITE, OR OLIVINE

Chrysolite, or **olivine,** is a silicate of magnesium and iron, $(Mg,Fe)_2SiO_4$.

Form: orthorhombic, but crystals are rare and usually small. It is commonly in grains scattered through rocks, or aggregated into pure, granular masses.

Hardness: 6.5 to 7, hard! *Specific gravity:* about 3.30.

Cleavage, not distinct, which aids in distinguishing it from pyroxene. *Fracture:* conchoidal. *Tenacity:* brittle.

Luster: vitreous. *Color:* usually some shade of green, either yellowish or olive-green.

Streak: usually colorless; must be obtained by powdering.

Transparent to translucent.

Occurrence: It is an important constituent of some volcanic rocks, such as basalt, diabase, gabbro and peridotite. Kimberlite, the matrix of the diamond, is an olivine-bearing rock. Platinum, chromite and garnierite are frequently found in olivine-bearing rocks. It is common in meteorites, especially in the stony-irons. One of the best known American localities is in Jackson County, North Carolina, where it occurs in showy granular masses of yellowish-green color.

Uses: When transparent it is cut into gems. Dark emerald-green olivine is highly prized. The olive-green stones are known as *peridot.*

CHLORITE GROUP

The chlorites owe their names to the characteristic dull, greenish color which they often have. They resemble micas in their foliated structure, but, while the thin plates may be bent, they are not elastic, but readily break.

Crystallized specimens are rarely seen except in museums, but the more massive forms are frequently found on hikes.

They are silicates of aluminum, magnesium and iron with water.

Clinochlore is the most attractive of the chlorites, occurring in lustrous, dark bluish-black to blackish-green, six-sided, monoclinic crystals at the Tilly Foster Mine, New York, also near West Chester, Pennsylvania, figure 239.

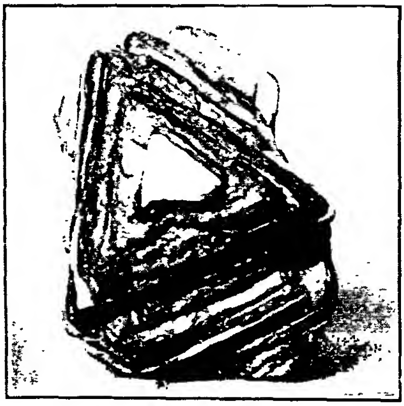


Figure 239 Clinochlore Crystal, West Chester, Pennsylvania

Penninite is very similar.

Diabantite is a dull green, granular-massive mineral often seen in the trap quarries.

Aphrosiderite is the grayish-green chlorite which forms from the alteration of garnet at Salida, Colorado and elsewhere.

Prochlorite is frequently seen enclosed in quartz crystals as a dull green, mossy formation or, less commonly, forming chloritic phantoms. It sometimes occurs in considerable deposits of granular-massive type, often forming the rock, chlorite-schist, as at Chester, Vermont. An odd, and not uncommon, occurrence is shown in figure 83. Here the crystals are strung out at a slight angle to each other into a worm like formation.

Be on the lookout for such curious freaks of nature. Their finding adds much to the zest of mineral collecting.

QUARTZ

Quartz, the commonest mineral, is silicon dioxide, SiO_2.

In many respects quartz is the most interesting of all minerals. It has a larger number of distinct varieties and there are wider differences between them than in the varieties of any other mineral. It is almost ubiquitous, for there are comparatively few places in the whole world where it would be possible to walk a mile and not see some quartz. A large mineral collection of great beauty and of much scientific and educational value and full of interest, can be formed exclusively from quartz.

Nearly all of the many varieties may be included in one or the other of two groups, those which are crystalline and those which are massive. Even the massive varieties, when examined under a high-power microscope, show a crystalline structure.

Varieties of Quartz

	Crystalline Varieties	Massive Varieties
Form	Hexagonal-rhombohedral crystals, or crystalline masses	Never in crystals visible to the naked eye, but a high power microscope shows that the mass is composed of exceedingly minute needle crystals
Cleavage	Rare	Unknown
Fracture	Subconchoidal	Uneven to subconchoidal
Tenacity	Brittle	Brittle to tough
Hardness	7.	7.
Specific gravity	2.66	2.60 to 2.70
Luster	Vitreous or greasy	Subvitreous to dull
Color	Colorless, violet, pink, yellow, brown, white, blue, green	White, blue, green, red, brown, gray, black, yellow
Streak	White	Same as mineral, but paler
Transparency	Transparent to sub-translucent	Transparent to opaque
Uses	Gems, decorative objects, dishes, vases, chemical apparatus, optical instruments, glass, sandpaper, cement, as a flux, for refractories.	Mortars, plaster, wood-fillers, pottery, soaps, semi-precious stones

(a) Crystalline Varieties of Quartz

Rock Crystal is *colorless, glassy quartz*, either in crystals or masses. The best occurrence in the United States is the doubly-terminated crystals found in limestone in Herkimer County, New York, figures 76–79, 240–242. Other notable occurrences of rock crystal are in Arkansas,

figures 91, 93, North Carolina, California, France and Switzerland Brazil produces more than any other country and largely supplies the commercial demand for the many optical uses to which it is applied, and for the material cut into beads and ornaments. Massive rock crystal abounds as part of many granites and similar rocks and can be distinguished by its glassy luster and hardness of 7.

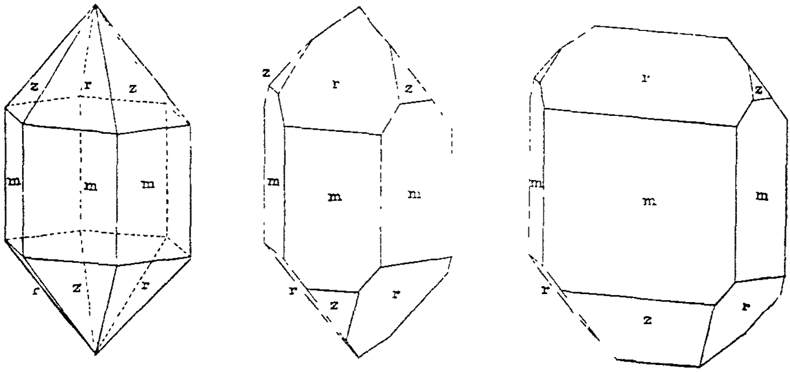


Figure 240–242. Quartz, Some Common Forms of Crystals

Amethyst is similar to rock crystal except that it has a beautiful purple to *violet* color. It has been prized as a gem since ancient times. Magnificent specimens come from Brazil, figure 131, Uruguay, the Ural Mountains, and many other localities. When heated, amethyst becomes a rich golden-brown and is sold at higher prices as "topaz."

Rose Quartz, figure 141, differs from rock crystal and amethyst in its *rose-pink* color and in practically never being in distinct crystals, but usually massive, sometimes forming large veins, as at Bedford, New York. It is cut into spheres and carved into many ornaments.

Citrine, also known by jewelers as "Spanish topaz" or "false topaz," is pale yellow in color and glassy. Brazil and Madagascar yield choice material for cutting into gems.

Smoky Quartz, often called "smoky topaz" and sometimes "cairngorm stone" (from the locality in Scotland), is a smoky-yellow to *smoky-brown* or nearly black variety. Magnificent crystals of large size have been found in Switzerland, figure 243, in Auburn, Maine and other localities. Smaller crystals, highly modified, occur in the Pike's Peak region, Colorado, in North Carolina and elsewhere. Massive smoky quartz often occurs in veins and is very common as part of many granites and similar rocks. It may be identified by its smoky color, vitreous luster and hardness of 7.

Milky Quartz is *milk-white* to snow white, sometimes in fine crystals, figure 244, but usually massive. It often forms large veins in other rocks

and is frequently gold-bearing. It is one of the commonest mineral ingredients of many rocks.

Sagenitic Quartz. Both crystals and masses sometimes enclose crystals of other minerals. If these are in needles the combination is known as *sagenitic quartz.* The commonest sagenitic quartz is that in which the

Figure 243. Smoky Quartz Crystal, St. Gothard, Switzerland

needles are rutile, and it is then known as *rutilated quartz.* When the enclosure is tourmaline, it is called *tourmalinated quartz,* figure 245.

Other Impure Quartz. Sometimes the whole mass of the quartz is densely filled with red or yellow iron oxides, as in *ferruginous quartz,*— or with *green chlorite* or *actinolite* or with *sand* or *mica.*

Aventurine Quartz consists of quartz enclosing minute scales of mica or hematite in parallel position, producing a spangled appearance.

(b) Massive Varieties of Quartz

Chalcedony is a very interesting variety of a waxy luster, usually translucent, but sometimes transparent, or again nearly opaque. It often occurs in curiously shaped concretions, or it coats or fills geodes, cracks

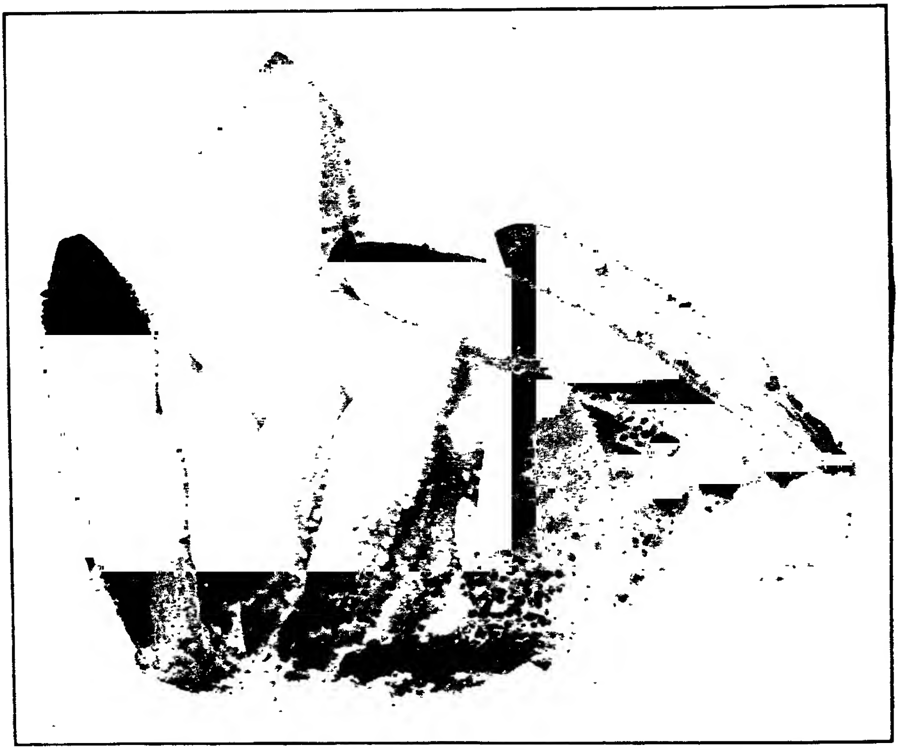


Figure 244. Milky Quartz, Group of Crystals, Ouray County, Colorado. Courtesy of J. G. Manchester

and cavities in decomposed rocks. Sometimes it is stalactitic, botryoidal, figure 123, or mammillary. It is usually white, gray, brown or bluish. It abounds in the Western United States, and at Tampa Bay, Florida, where it occurs in geodes, many of which are pseudomorphs after coral; also abundant in Brazil and many other localities.

Carnelian is a red chalcedony. It grades from deep blood-red to pale red and brown, the last named being called *sard*. The ancients used these stones for carving intaglios and cameos, the intense red colors being the most highly prized.

Chrysoprase is an apple green chalcedony of much beauty when cut in cabochons. It was highly esteemed by Queen Victoria. Germany and California are the chief localities.

Agate is a variegated chalcedony. There are many types, but *banded agate,* figure 121, is best known. In some specimens the bands are coarse, as much as a quarter inch or even more; on the other hand, Sir

Figure 245. Quartz Enclosing Needles of Tourmaline, Cross-Section of Crystal, Jefferson County, Montana

David Brewster, using a microscope, counted 17,050 in a single inch. The layers differ not only in color and translucency, but also in compactness. This variation in their texture makes it possible to artifically color agates, thus producing rich reds, yellows, blues, greens and browns in place of the original dull gray, white or brown. Most agates as offered in the world's markets are artificially colored. There is much of interest to be learned about agates and the beginner will find it well worth his while to read up about these beautiful objects.

Not all agates are banded; some are irregularly mottled and clouded; others have enclosures of black or green resembling moss and are called *moss agates;* in some, manganese oxide filters in between the layers and is deposited in tree-like or fantastic shapes forming *landscape agates* or *tree agates*, figure 138.

Onyx is a variety of agate in which the bands are straight, and as the layers are even, it is well adapted to use in cameos. "Mexican onyx" is not a variety of quartz, but of calcite and is described on page 261.

Sardonyx is a red and white onyx.

Bloodstone, also sometimes called *heliotrope,* is too nearly opaque to be properly regarded as a variety of chalcedony. It has a peculiar grayish-green color and through this there are sprinkled bright red spots from whose resemblance to blood the name of the mineral is derived. It is prized in ring stones.

Flint, figure 246, is familiar to every boy scout, for with its aid he can light a fire. It is much less translucent than chalcedony and is a typical illustration of a semi-translucent mineral (see page 103) or one

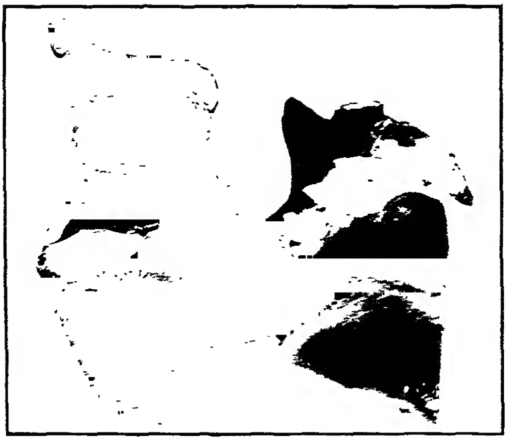


Figure 246. Quartz, variety Flint, Nodule, Dover Cliffs, England

which transmits light only on very thin edges. Its luster has very little resemblance to the vitreous luster of rock crystal, yet if it is examined carefully it will be noticed that there is a little glisten to it, and it is customary, therefore, to call its luster subvitreous. Flint usually has a dull gray color; sometimes it is more proper to call it smoky-brown or brownish-black. If you try to break a piece of it you will quickly conclude that its tenacity is great, or, to put it another way, it is tough. You will also note that when it does break it leaves a deep-conchoidal fracture and an unusually sharp cutting edge. The American Indians were quick to recognize its advantages in their making of arrow heads and other implements.

Chert, or hornstone, is similar to flint, but more brittle and splintery and less pure. It is abundant in Missouri and Arkansas.

Jasper is opaque, massive quartz, usually red, brown, yellow or dark grayish-green. It is sometimes attractively banded with rock crystal, or two or more colors of jasper may be in parallel stripes, forming *ribbon* jasper. Some of the showy types of jasper are cut into ring stones or are used for larger decorative objects or for wainscoting or table tops. It is widely distributed, notable occurrences being in South Africa and Siberia.

(c) Fragmental Varieties of Quartz

Quartz sand results from the weathering of rocks containing quartz, and the subsequent grinding of the released quartz masses, one upon another until they are greatly reduced in size and often rounded into grains more or less spherical in form. Any of the varieties of quartz may be thus reduced to sand, but as rock crystal, smoky and milky quartz are much the most common varieties, grains of them are more plentiful in sands than grains of any other varieties. A collection of sands from all over the world, however, will show quartz of a great variety of colors and degrees of transparency. Sands found close to their source of supply are often quite sharp and angular, but those which have been transported by streams for hundreds of miles and especially those which have been subjected to the action of ocean waves are always much rounded.

The study of rocks will show how sands are consolidated into *granular sandstone,* how it, in turn, is changed by heat and pressure into *quartzite;* how sharp fragments of quartz are consolidated into *quartz-breccia;* how rounded quartz pebbles are consolidated into *quartz-conglomerate.* While all of these rocks usually have impurities included in them and cannot be regarded as minerals, nevertheless the beginner should aim to recognize them as being largely composed of the mineral quartz.

(d) Pseudomorphous Quartz

Lastly, there are occurrences of quartz in the form of other minerals or objects of any kind. Among the most abundant types are quartz pseudomorphs after shells, after wood, after corals, after fluorite, barite, calcite, siderite.

Petrified wood, or *silicified wood* is the commonest illustration of a quartz pseudomorph. The wood is slowly replaced, cell by cell, by silica, until not a trace of the original material remains, (see page 101). One of the most striking instances of such formations is the Petrified Forest of Arizona, a scene in which is pictured in figure 135. The gorgeous red and yellow colors of this material are due to oxides of iron.

OPAL

Opal is silicon dioxide, plus an indefinite amount of water. The formula is written $SiO_2.nH_2O$,n usually signifying from 3 to 9 per cent water, but it varies from 2 to 13 per cent, or even more.

While opal seems very near to quartz in its chemical composition it is very different from it in several respects. It is *never crystallized,* indeed it has absolutely no crystalline structure and is, therefore, called *amorphous.* It is far more *brittle* than quartz, and its *hardness* is less, varying from 5.5 to 6.5, while its *specific gravity* averages only about 2.15.

Luster: vitreous, resinous or dull. *Streak:* white.

Colors: numerous, as noted below.

Transparent to opaque.

Opal is a common mineral and occurs in many varieties, some of which are not at all attractive, while others are among the most magnificent and costly of mineral specimens. The magazine "Rocks and Minerals" devoted its entire March 1933 issue to opals, publishing many interesting articles.

Precious opal owes its superlative beauty and its popularity as a gem to its gorgeous *play of colors* (see pages 116, 117), or, as Farrington playfully put it, to "colors at play." Nineteen hundred years ago Pliny wrote of it that it "presents various refulgent tints in succession, reflecting now one hue and now another. It is made up of the glories of the most precious gems. There is in it the gentler fire of the Ruby, the brilliant purple of the Amethyst, and the sea-green of the Emerald, all shining together in an indescribable union." The precious opal was the "lucky-stone" of the ancients. The Roman Senator Nonius, who owned the greatest opal then known valued at the equivalent of about $800.000, U. S. money, went into exile rather than surrender his "good luck gem" to Mark Anthony.

Many names have been given to different types of precious opal, or as it is often called, "noble opal," and descriptive names have been applied to individual gems and to the mines, such as "the flaming forest," "the volcano," "the royal peacock," "rainbow ridge."

Until the latter part of the nineteenth century the finest gem opals came from Czernowitza, Hungary, now in Czechoslovakia. They always commanded high prices. In 1886 precious opals of deep, rich peacock-blue were found in an iron-jasper in Queensland, Australia and were placed on the market at but a small fraction of the prices previously charged for Hungarian stones. They immediately aroused unparalleled enthusiasm. During the next thirty or forty years very important finds were made in New South Wales and South Australia, with the result

that practically all opal gems used in the jewelry trade now come from Australia. Only a few isolated specimens of precious opal had come from the Western United States until about 1908 when magnificent specimens were found in abundance over a considerable area in Humboldt County, Nevada. No other region has ever produced so great a variety of superlatively beautiful specimens of precious opal. Small specimens are now within the reach of every collector.

Fire opal is bright brownish-red to yellowish red, either with or without the play of colors. The finest gems come from Queretaro, Mexico.

Milk-opal is milk-white to snow-white, without any play of colors: if it shows play of colors it is classified as precious opal.

Common or semi-opal includes varieties of resinous or waxy luster: yellow, brown, brick-red, dull green or black color.

Opal-agate is common opal of any color, with banded structure.

Wood-opal, figure 136, is wood changed to opal, or opal pseudomorph after wood, see page 101. It is plentiful in the western United States, especially in Humboldt County, Nevada, in which section opalized wood occurs magnificently spangled with gorgeous precious opal.

Hyalite is a colorles opal, clear as glass, often forming crusts on rocks, and having a botryoidal surface, or occurring as small spherical concretions, figure 129.

Geyserite, or *silicious sinter,* forms around the geysers of the Yellowstone Park, New Zealand and Iceland, in concretionary deposits often of much beauty and resembling mushrooms, cauliflowers, and other objects. It is opaque; white or gray; soft, porous, and at times, in filaments.

Diatomaceous earth, diatomite, or *infusorial earth,* is formed from the silicious shells of diatoms and other minute forms of life. It is either compact-massive, or loose as a very fine-grained white or gray earth, resembling chalk or clay, but with a gritty feel and hard enough to scratch glass. It occurs in beds of great size (up to 4700 feet thick) in California, and is also found in Nevada, Virginia and elsewhere in the United States and in many foreign localities. It is used as an abrasive in polishing and scouring powders, as a filter-stone, in making water-glass, various pigments and for many other purposes.

SERPENTINE AND TALC GROUP

This group includes a few common minerals which are similar, in some respects, to the chlorites. They are silicates of magnesium with water, and do not crystallize. They have been formed by the alteration of other minerals, such as chrysolite and enstatite.

Serpentine, hydrous magnesium silicate, $H_4Mg_3Si_2O_9$, though it *never crystallizes,* is found in an unusual variety of forms, some of which are very attractive. It is quite remarkable how it varies in ***hardness,*** all the way from 2.5 to 5.5, but as a rule the range is between 2.5 and 3. so that it is easily scratched. Its *specific gravity* is around 2.50.

Varieties: Precious serpentine includes those quite pure, massive types, with *hardness of 2.5 to 3,* which are *translucent* and of *rich colors,* either bright yellow or green. These grade off, through addition of impurities, into *common serpentine,* whose *hardness may run up to 4 or even higher,* and which is *semi-translucent* to nearly opaque, and lacks the beauty of precious serpentine, its colors being usually dull.

Serpentine marble is the name given to any kind of serpentine when it is polished and used as a decorative stone. Some of these so-called marbles are very popular, the most widely used being *verd-antique,* in which the dark green or bright red serpentine, is veined or mottled with a white mineral, usually dolomite. By far the most important variety, from a commercial standpoint, is *chrysotile,* known in the trade as *"asbestos,"* though true asbestus is a variety of amphibole. Chrysotile is fibrous and can readily be separated into very fine, flexible fibers having a silky luster. *Picrolite* is a variety in long, coarse fibers, not easily separated nor flexible. There are many other varieties.

Fracture: subconchoidal or splintery. *Tenacity:* Massive varieties are usually tough; fibrous varieties, more or less flexible.

Luster: Massive varieties have little luster, but are commonly oily, or resinous; fibrous varieties have a bright, silky luster. *Streak:* white.

Non-inflammable and a *non-conductor of heat.*

Occurrence: Serpentine often forms large rock masses and is quarried as a building stone near Philadelphia and Baltimore. Serpentine marbles of much beauty occur abundantly in Vermont, England, Ireland, Italy, France, Greece, and many other countries. A bluff of common serpentine may be seen from the North River boats passing Hoboken, New Jersey. Chrysotile of superfine quality is extensively mined in Quebec, Arizona, the Transvaal and Southern Rhodesia.

Uses: extensively used as a building or decorative stone. The precious variety is employed to some extent in small decorative objects. The great importance of serpentine is due to the ease with which the fibrous chrysotile can be spun into yarn or thread and woven into fire-proof fabrics or felted into sheets or packing, used for shingles, pipe coverings, lining stoves, safes and many other uses.

Talc is a silicate of magnesium, with water, $H_2Mg_3Si_4O_{12}$.
Hardness: number 1 in the scale of hardness.

Specific gravity: about 2.8.

Form: monoclinic, but crystals are almost unknown. It is abundant, either compact as *steatite* or *soapstone,* or in the rock *"talc-schist."* The purer kinds have a *foliated structure,* separating readily into thin plates which are *flexible,* but not elastic. *Fibrous* varieties are not uncommon, often due to admixture of tremolite, as at Edwards, New York.

Cleavage: basal.

Tenacity: sectile. *Feel:* soapy.

Luster: pearly to greasy.

Color: Soapstone is generally gray; foliated talc is usually white or sea-green.

Streak: white. *Transparent* to nearly opaque.

Not attacked by acids; also heat resisting.

Occurrence and *Uses:* It is a very common mineral and widely distributed. An impure soapstone at Alberene, Virginia is used for laboratory tables and tanks, washtubs, switchboards, etc. The compact talc of western North Carolina is made into crayons and is cut into "lava tips" for gas burners which, when heated to a high temperature become very hard. Ground fibrous talc from Northern New York is extensively used as a filler for paper, in paints and for many other purposes. The finest quality of foliated talc comes from Providence, Rhode Island.

STAUROLITE

Staurolite is a silicate of iron and aluminum, with water, $HFeAl_5Si_2O_{13}$.

Hardness: 7 to 7.5, very hard. *Specific gravity:* about 3.7.

Color: usually dark brown. *Luster:* vitreous to dull.

Opaque: or rarely transparent.

Form: orthorhombic. Simple crystals rather rare. It is most remarkable because of the abundance of its *twins* of several types as shown in figures 100 and 101. These abound in many localities and can sometimes be collected by the hundred pounds. Superstition naturally attaches to the right angle crosses which are worked up into amulets and sold as "cross stones" or "fairy stones." The name staurolite, indeed, is derived from the Greek, *stauros,* a cross and *lithos,* stone.

Occurrence: usually found in mica schist, often associated with kyanite. Plentiful throughout the New England States, Virginia, North Carolina and Georgia. Faido, Switzerland and Brittany, France, yield choice specimens.

TOURMALINE

Tourmaline is a very complex silicate, always containing boron, aluminum and water, and sometimes iron, magnesium, sodium, lithium or even chromium.

Hardness: 7 to 7.5, a little harder than quartz.

Specific gravity: 3.0 to 3.20. *Luster:* vitreous inclining to resinous.

Color: usually black, sometimes brown, but not uncommon of bright, showy colors, especially green and red or pink, less frequently yellow, blue or colorless. The red or pink variety is called *rubellite,* the blue is *indicolite.* Very fine gems are not uncommon. Single crystals often show different colors at the respective ends, or may have a core of a different color from the exterior, or there may be a most attractive banding of colors. The *dichroism* has been mentioned on page 104.

Streak: uncolored. *Transparent* to *opaque.*

Electrical properties: A crystal is easily charged with electricity either by friction or by heating it, and shows positive at one end and negative at the other.

Form: Crystals are *rhombohedral,* the terminal faces at one end often being rather flat rhombohedrons or scalenohedrons, frequently combined with the base. A prismatic development is customary, the prisms usually being long, figure 247, and sometimes extended into capillary forms, which may be enclosed in rock crystal, thus producing *tourmalinated quartz,* figure 245, the color being black or bluish-gray, as in Montana, Utah and Brazil. Prismatic crystals are often deeply striated, see figure 90, page 66. If the faces are well developed they are in threes, sixes or nines. *Columnar* tourmaline is not uncommon, and, if black, would be difficult to distinguish from black hornblende were it not for the fact that the mineral has practically *no cleavage.*

Tenacity: brittle, though the gem varieties are less so.

Occurrence: Tourmaline is a very common mineral in many kinds of rocks, but especially in granite, gneiss and the coarser phase of granite, pegmatite. It is rare in limestone, and then usually brown as at Gouverneur, New York, or grayish-green as at Franklin, New Jersey. If associated with lepidolite, it is usually light-colored and gemmy, while if associated with cassiterite it is apt to be black. At times the black variety is so plentiful in granite as to lead to the name "tourmaline-granite." The finest black crystals come from Pierrepont, New York. The localities in Maine, California, Madagascar and Brazil are world-famous for their beautiful green, pink, deep red, blue and vari-colored crystals and gems. Many other localities, too numerous to mention, yield tourmaline crystals so attractive as to make this one of the most delightful of all minerals.

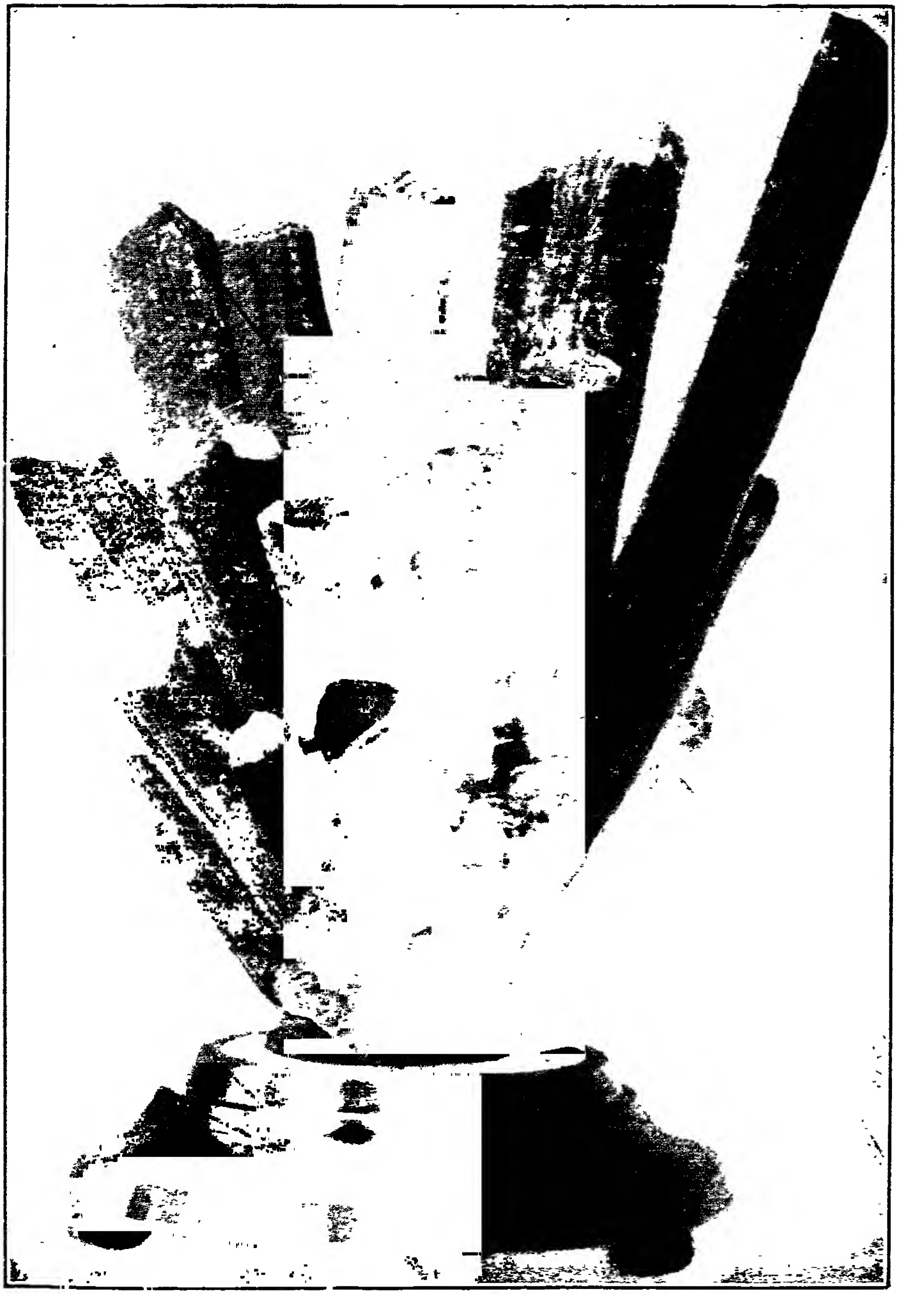


Figure 247. Tourmaline, Group of 32 Black Crystals, Largest 18 Inches Long, Weight 42 lbs. in American Museum of Natural History. Courtesy of J. G. Manchester

THE ZEOLITES AND ASSOCIATED MINERALS

(a) The Zeolites

The zeolites are an interesting group of about three dozen hydrous silicates in which aluminum is always present in larger quantity than any other metal. Calcium is nearly always present, but sometimes it is replaced by sodium, or more rarely, potassium, while occasionally barium is present and in one species, strontium. The following table shows the composition of the more important zeolites and also of four minerals which are frequently associated with them:

Composition of Zeolites and Associated Minerals

Zeolites:	H_2O	SiO_2	Al_2O_3	CaO	Na_2O	
Heulandite	14.8	59.2	16.8	9.2		
Stilbite	17.2	57.4	16.3	7.7		
Chabazite	21.3	47.4	20.2	11.1		
Analcite	8.2	54.5	23.2	...	14.1	
Natrolite	9.5	47.4	26.8	...	16.3	
Scolecite	13.8	45.9	26.0	14.3	...	
Mesolite	12.4	46.4	26.3	9.6	5.3	
Associated Minerals:						
Pectolite	2.7	54.2	...	33.8	9.3	
Apophyllite	16.1	53.7	...	25.0	5.2	K_2O
Datolite	5.6	37.6	..	35.0	21.8	B_2O_3
Prehnite	4.4	43.7	24.8	27.1		

All of the zeolites are secondary minerals, that is they have been formed by the alteration of primary or previously existing minerals. Usually the original mineral was a feldspar or one of the feldspar-like minerals, which gives rise to another name for this group, "hydrous feldspars."

They usually occur in cracks in basalt, or diabase, but occasionally in granite or gneiss. The zeolites abound in the trap rocks of The Palisades of the Hudson River and nearby localities, such as Paterson, New Jersey; also in Connecticut and Nova Scotia. Many other important localities might be mentioned, including especially Iceland, the Faroe Islands and India.

Their *hardness* is not great, ranging from about 3.5 to 5.5. *Specific gravity* is under the average, about 2.0 to 2.4.

Heulandite has a *hardness* of 3.5 to 4 and occurs in somewhat coffin-shaped, monoclinic *crystals*, often of considerable beauty, because of their pearly *luster*. This, however, only appears on the "side" face,

which is always designated in monoclinic crystals by the letter *b*. The other faces have a bright vitreous *luster*. Somehow this *b* face has a habit of turning itself up on the rock, giving the impression of its being the base and as there is a distinct *cleavage* parallel to it, a beginner may easily err by calling it a basal cleavage, which it is not. Large crystals are often made up of smaller ones in nearly parallel position. The *color* is usually white, sometimes tinted yellow or brown, while a locality in the Tyrol yields brick-red crystals. Paterson, New Jersey, has produced the finest specimens found in this country, but even more magnificent specimens come from Iceland.

Stilbite has the same *hardness* as heulandite, 3.5 to 4, the same pearly and vitreous *luster*, the same *cleavage*, and sometimes much resembles it. It is very different, however, in its most characteristic form, a double sheaf, as shown in figure 248. Though often of white *color*, it is frequently grayish-brown. Its occurrences are identical with heulandite.

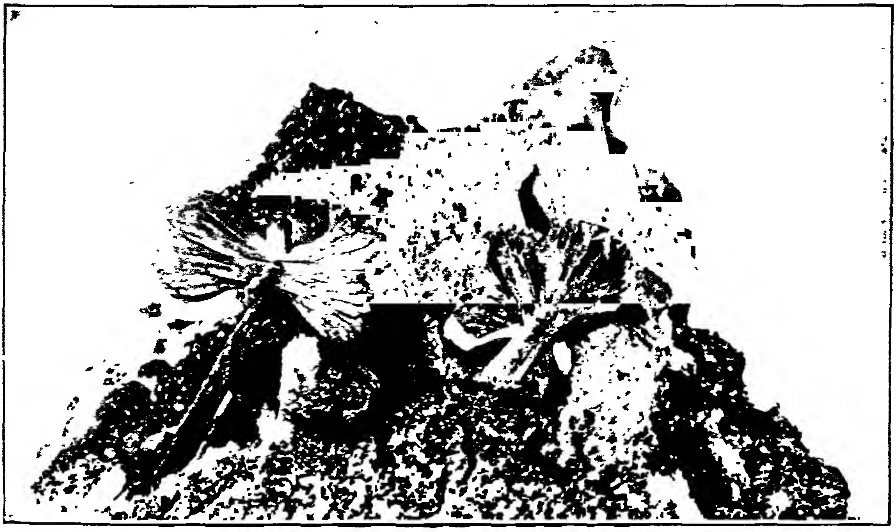


Figure 248. Stilbite, Sheaf-like Group of Crystals, Upper Montclair, New Jersey

Chabazite is somewhat *harder* than heulandite and stilbite, 4. to 5. It is easily distinguished from all other common zeolites by the rhombohedral forms of its *crystals* and its rhombohedral *cleavage*. Its *luster* is vitreous, never pearly. White is the common *color*, but Nova Scotia abundantly produces groups of very charming flesh-red crystals to which the name *acadialite* has been given. White chabazite from certain localities has been used in purifying helium gas.

Analcite is decidedly *harder* than most other zeolites, being 5. to 5.5 and its *crystals* are easily identified because they are usually isometric trapezohedrons, figure 249. The *cleavage* is cubic but not very distinct. Its *luster* is vitreous, but in New Jersey, the nearly opaque crystals are not usually as brilliant as are the transparent crystals from Lake Superior, Sicily and other localities.

Figure 249. Analcite Crystal on Rock, West Paterson, New Jersey. Courtesy of J. G. Manchester

Natrolite, "needle zeolite," figure 250, differs strikingly from all the zeolites previously mentioned, as it usually occurs in slender needles, or radiated-fibrous masses. Its *crystals* are orthorhombic, often nearly square prisms, terminated by quite flat pyramids, which help to distinguish it from scolecite, which often looks much like it. If crystals large enough to cleave are available, prismatic *cleavage* will be found well developed. Its *luster* is vitreous, or somewhat pearly in the fibrous forms. *Color:* almost always white, rarely yellow or red. Magnificent specimens have been found in New Jersey, Bohemia and elsewhere.

Scolecite often very much resembles natrolite. It has the same *hardness, cleavage, luster* and method of *occurrence* in slender crystals

and radiated masses. Its *crystals* also, though monoclinic, have almost the same angle between the prism and the terminal faces. Both minerals form a jelly when treated with acids. When heated, however, a marked difference is noticed, for natrolite fuses quietly to a clear glass, while scolecite fuses to a white enamel, full of bubbles, and sometimes in doing so it will swell up and curl like a worm. Its crystals often show feather-like markings on the side faces. Very fine specimens come from Iceland and India.

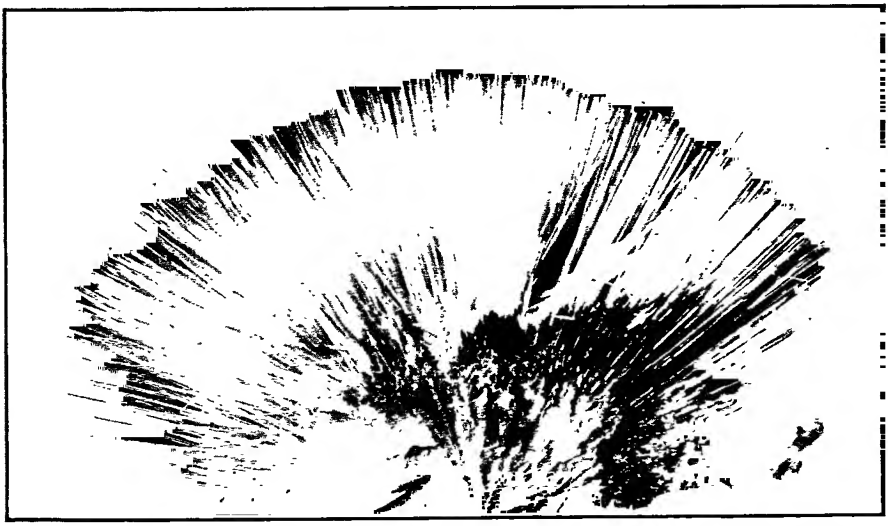


Figure 250. Natrolite, Group of Radiating Crystals, West Paterson, New Jersey. Courtesy of J. G. Manchester

Mesolite is similar to natrolite and scolecite, but the needles are usually much finer and often matted into a felt, figure 251, though sometimes it occurs in compact masses with a radiated structure. Golden, Colorado, yields excellent specimens, associated with another zeolite, **thomsonite,** and with *analcite.*

(b) Minerals Associated with the Zeolites

Pectolite, a calcium-sodium silicate, is usually found in compact-fibrous masses with a radiated structure. Rarely terminations of distinct monoclinic crystals are found on the edge of more or less completely spherical masses, as at Paterson, New Jersey, which is its best-known American locality. Its *hardness* is 5; *specific gravity:* about 2.68 to 2.78, only slightly heavier than quartz. *Color:* white or grayish. Usually *opaque. Luster:* silky to subvitreous. The more highly crystalline varieties break into thin, sharply-pointed slivers, which are very

apt to stick in the fingers and cause considerable irritation. A massive variety, of very tough texture, occurs in California and Alaska, and has been used by Indians as a substitute for jade.

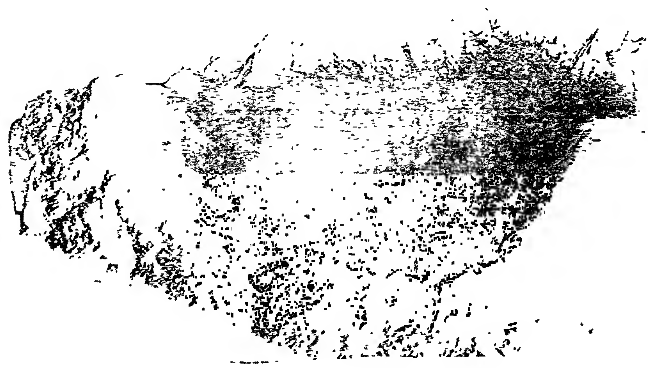


Figure 251. Mesolite, Matted Crystals, Golden, Colorado

Apophyllite is a hydrous silicate of calcium and potassium, so much like the zeolites in many ways that some writers include it in that group. Its chief difference, from a chemical standpoint, is that it contains no aluminum, which is one of the essential ingredients of all true zeolites. Its *hardness* is 4.5 to 5; *specific gravity:* about 2.35. Its *crystals* are tetragonal and vary much in habit, though specimens from any one locality usually have the same form. Those from Mexico, the Harz Mountains and some other prominent localities are like figure 40. Looking at the Lake Superior crystals, however, we see that while showing the same faces, they also have the base, *c*, present and highly developed, thus producing tabular crystals. Crystals from Paterson, New Jersey, however, have the prism and the base about equally developed, thus giving the appearance of almost cubical crystals, figure 252. The base always shows a beautiful pearly *luster*, while the other faces are vitreous. The crystals are often colorless and transparent, sometimes white, rarely a delicate pink.

Datolite is a silicate of calcium and boron; a *composition* very different from any of the zeolites. It occurs in highly complex, monoclinic

Figure 252. Apophyllite, West Paterson, New Jersey

crystals, figure 253, eighty-six forms being listed in Dana's "System of Mineralogy," and doubtless many more are now known. It usually occurs in groups of *transparent* or translucent crystals, varying in size up to two or three inches, and colorless or pale yellowish or greenish *color* and vitreous *luster. Hardness* is 5. to 5.5; *specific gravity:* about 3.0. It was formerly abundant in the New Jersey zeolite localities and at Westfield, Massachusetts.

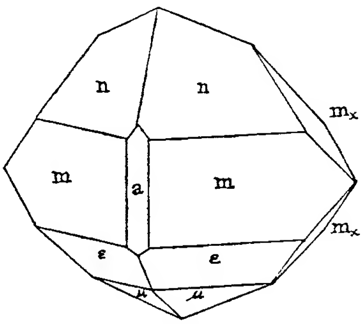


Figure 253. Datolite, a Common form of Crystal

Prehnite is a silicate of calcium and aluminum yielding a little water when heated; formula is $H_2Ca_2Al_2Si_3O_{12}$.

Its *hardness* is 6. to 6.5, quite hard; *specific gravity:* about 2.9.

Its *color* is ordinarily pale apple-green, but sometimes pale yellow or grayish-white. *Luster:* vitreous, but not bright.

It usually occurs in crystalline masses, more or less globular or mammillary, and often coating the rock. Its *crystals* are orthorhombic, but rarely occur except in rounded, or somewhat barrel-shaped, groups with repeated sharp edges. Paterson, New Jersey, is noted for its fine specimens, one of which is pictured in figure 254.

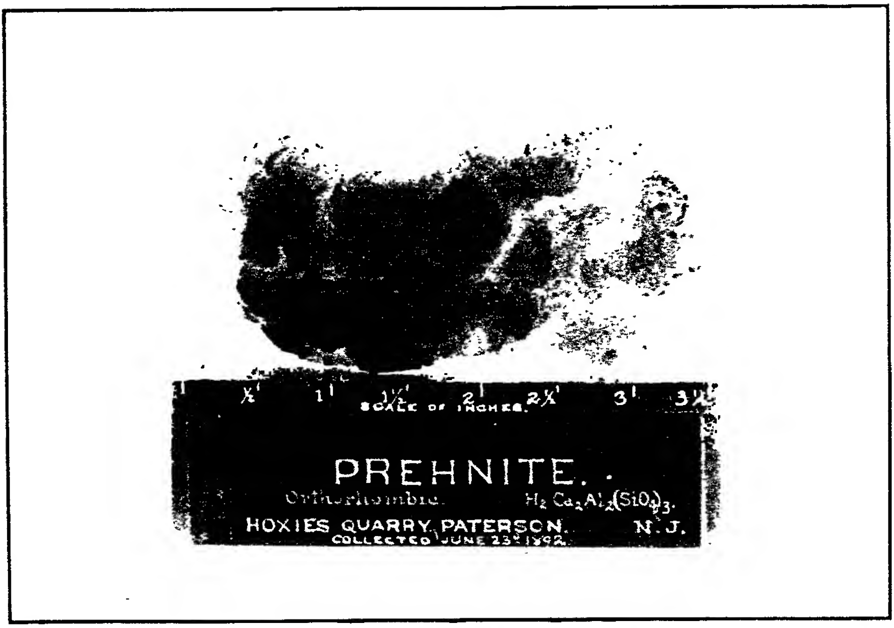


Figure 254. Prehnite, Paterson, New Jersey

PART III

DESCRIPTIONS OF ROCKS

PART III

ROCKS: THE CRUST OF THE EARTH

When we think of the Earth it is natural to imagine it as made up of land and ocean. These together constitute, however, only the comparatively thin crust of the Earth. We know almost nothing, as to what is deeper down than 11,000 feet, though many scientists believe that the interior of the Earth is largely iron. Careful estimates of the relative quantities of the materials making up the crust of the Earth have been made and it has been established that the feldspar group of minerals is much more abundant than any other, followed by quartz, these two together constituting over half of the crust.

The student is likely to be much more interested in the beautiful forms and colors of minerals than in the usually formless masses of rocks which seem to him, in many instances, to have so little definite character as to make their identification impossible. It is, nevertheless, well worth while to know something about the rocks and a little study of them will prove more interesting than might, at first, seem probable. Some of the rocks are certainly attractive and there is one charm which they possess to a marked degree, namely variety. A series of typical rocks can be purchased at small cost and will prove very helpful in their study.

THE THREE GROUPS OF ROCKS

Rocks are usually divided, according to their origin, into three great groups:

I. Igneous
II. Sedimentary
III. Metamorphic

I. IGNEOUS ROCKS

All igneous rocks were once in a liquid state, their present solid condition being due to a cooling or "freezing" of the material. We learned, in chapter 4, something about the chemical elements and their compounds. In nature's vast laboratory, far beneath the surface of the earth, these elements combine with each other to form minerals; then the crystalline particles of different minerals interlock with each other to form the igneous rocks.

(a) Coarse-grained Igneous Rocks

Granite is a coarse to medium-fine grained, light colored rock, having an even texture, composed of quartz and feldspar, with either mica or hornblende or both. The feldspar is easily recognized by the sparkle of its cleavage surfaces. It may be white, creamy, flesh color, pink or red of various shades, or, more rarely, yellow. The quartz is clear, milky or smoky and has a glassy luster and no cleavage. The mica is either silvery-white or colorless muscovite, or black biotite, or both may be present. If the flakes are large enough they may be scaled off with the point of a knife. If hornblende is present, it has a greenish-black color and prismatic instead of micaceous cleavage. Granite is one of the most abundant and important of rocks. It is hard, takes a high polish and is durable, thus fitting it for its wide use as a building and monumental stone.

Pegmatite is a very coarsely crystalline granite, occurring in veins or dikes cutting ordinary granite. It is the chief source of the feldspar and mica of commerce and frequently contains other minerals of economic importance, such as gem varieties of tourmaline, beryl and topaz, also many minerals containing the rarer elements.

Syenite resembles granite except that it contains little, if any, quartz. It is used as granite in buildings and is equally durable. An important variety contains nephelite and is called *nephelite-syenite.* Another variety, called *anorthosite,* is composed almost entirely of labradorite. It abounds in the Adirondack Mountains in New York and in Canada and Labrador.

Diorite is a greenish-black or dark grey igneous rock, with medium or coarse grains and even texture. It usually consists chiefly of hornblende or pyroxene, which gives it its color, and a smaller quantity of feldspar. Biotite-mica may be present, sometimes in considerable quantities, and pyroxene may replace some of the hornblende. Quartz is notably absent. If present, the rock is called *quartz-diorite.* Diorite is a common rock type in many localities, for example at Bergen Hill, Jersey City, New Jersey.

Diabase, is a related rock usually of fine texture, yet often showing to the naked eye, lath-shaped feldspars embedded in augite. Olivine is often present while magnetite is almost invariably present.

Gabbro is another common rock, so similar in appearance to diorite that it is difficult to distinguish between them. The chief difference is that pyroxene or hornblende is the preponderating mineral with feld-

spar in smaller quantity, no quartz being present. The color is about the same as diorite, greenish-black, or dark gray, and the texture is even. How to distinguish between pyroxene and hornblende is explained on page 214.

Dolerite is a rock name which has been used with varying meanings, but the best American practice is to define dolerite as a fine-grained variety of either gabbro or diorite in which the dark-colored minerals may be either hornblende or pyroxene, but whose particles are too small to be distinguished with the naked eye.

Peridotite is a name given to green to black, coarse grained or medium-coarse-grained rocks, consisting almost entirely of iron-magnesium minerals. In peridotite proper the minerals are largely olivine with less pyroxene or hornblende. *Dunite* is a nearly pure olivine variety and is familiar to American collectors as the mineral chrysolite of Jackson County, North Carolina. *Cortlandtite* is a variety consisting of olivine and hornblende. It is found at Syracuse, New York and elsewhere. *Kimberlite* is a variety of peridotite, interesting chiefly because diamonds are found in it in South Africa, Arkansas and elsewhere. It is ordinarily a great jumble of minerals, indeed, it has been playfully described as a mineral collection in itself, but, typically, it is a porphyritic rock, consisting largely of olivine and some mica, with inclusions of other minerals. *Pyroxenite* is a nearly pure pyroxene variety of peridotite, while *hornblendite* is a nearly pure hornblende variety.

(b) Fine-Grained Igneous Rocks

Lava is a broad term which includes the material which flows out of volcanoes.

The fine-grained rocks, of igneous or volcanic origin, may be roughly classified under two headings, felsite and basalt.

Felsite and Basalt. Felsite includes all dense, fine-grained rocks, of a stony texture, which are not very dark in color. The dark colored are called **basalt.** The colors of felsite vary greatly and include gray, light pink to dark red, purple, light green and yellow to brown, and, less commonly, white. *Basalt*, almost always is black or very dark green.

To the naked eye it is impossible to distinguish the individual minerals in felsite and basalt, and even though a lens may reveal fine grains, they are too minute to determine their characteristics, while not infrequently the grains may be too fine to be seen even with a lens, in which case felsite has a flinty appearance and conchoidal fracture while

basalt has a velvety luster and does not break with a conchoidal fracture.

The advanced student of rocks, by the aid of the microscope, is able to identify the minerals even though their particles be exceedingly small, but without the microscope this is impossible, so that the best the beginner can do is to divide the fine-grained volcanic rocks into the two major classes of felsites and basalts. It is worth learning, however, that by microscopic study the lighter-colored felsites are found to consist chiefly of feldspars and the darker-colored basalts of pyroxenes or hornblendes. If a thin edge of a felsite is held to the light, it will appear translucent while a thin edge of a basalt will be opaque because the feldspars are translucent while the rock-forming pyroxenes and hornblendes are opaque.

Dependent upon the minerals they contain many rock names have been introduced for varieties of felsite and basalt. The beginner can do little more than learn their names and look forward to the day when he will be able to enjoy their study with the microscope. The most important varieties of felsite are *rhyolite* and *trachyte; dacite, andesite* and *phonolite* are other less common varieties. The *compact basalts, often called "trap,"* vary but little in general appearance, though under the microscope wide variations in mineral composition may be noted. Frequently, however, a porous structure is seen and many minerals are found in the cavities. Such rocks are called *amygdaloidal basalt.*

Porphyry. If one or more of the component minerals of the rock crystallizes out, more or less perfectly, thus giving the rock an attractive spotted appearance, it is called a *porphyry.* Porphyries occur in granite, diorite and many other rocks besides the felsites and basalts. One of the most spectacular of the *basalt porphyries* is the so-called *labradorite porphyry* pictured in figure 255, in which the coarse, light-colored crystals are labradorite. Such crystals are called *phenocrysts. Felsite porphyries* are much commoner, especially in the variety rhyolite.

Glassy Rocks. If the output of a volcano cools very rapidly, the elements do not combine to form definite minerals, but merely a volcanic glass. If the entire rock is made up of this glass and it has a vitreous luster, it is called *obsidian:* if its luster is greasy it is *pitchstone:* if it is distinctly cellular it is *pumice.* Obsidian is notable for its conchoidal fracture, see figure 112, page 81, and the very sharp edges produced, which cut like glass. Indians formerly used obsidian for knives. The color of obsidian is commonly pure black: less frequently brown or red. Pitchstone is oftener brown, though at times gray or black. Pumice is usually gray and so light because of its cellular structure, that it will

float on water. It is produced by the penetration of the volcanic gases into obsidian. It is used as an abrasive and may be bought at any drug store.

II. SEDIMENTARY ROCKS

The materials of which sedimentary rocks are composed have come from other previously existing rocks, but they have been formed by two

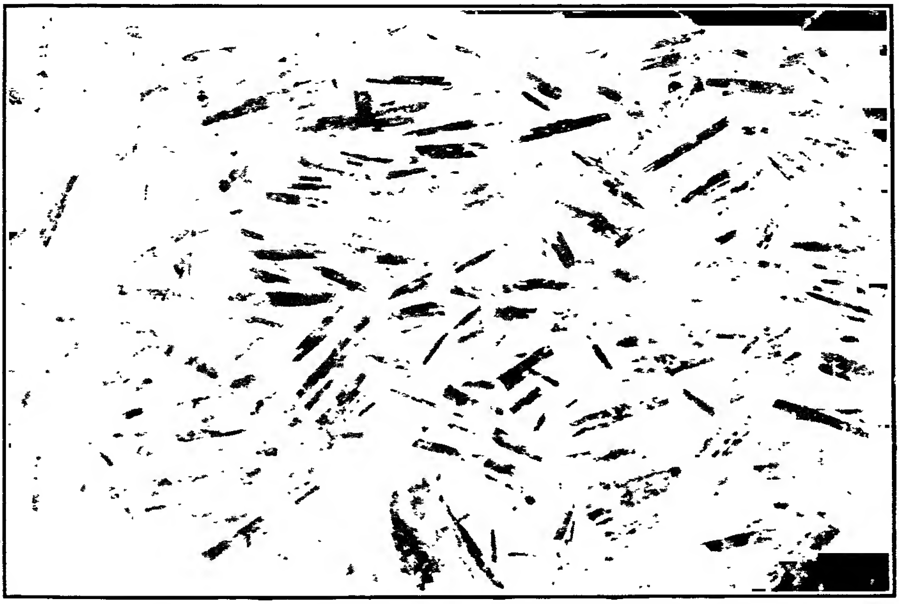


Figure 255. Labradorite-Porphyry, Marshfield, Massachusetts

very different methods. Based on their origin, the sedimentary rocks are grouped under (a) those of mechanical origin and (b) those which have been chemically precipitated.

When we look at a towering mountain it seems as though no forces could be powerful enough to cause its destruction. There are, however, enemies at work all around it. We can scarcely overestimate the destructive power of the atmosphere, silently working throughout the centuries to tear it down. Then, too, water seeps into any cracks in the rocks and, by freezing, forces them apart and gives the rains the opportunity to wash them down. Each piece rubs the one next to it and thus they reduce each other to small fragments which, in turn, grind each other to still smaller pieces which the rains carry down into the streams. Here the fragments wear each other still more until eventually, when they reach the oceans, they are but tiny grains of sand. This process of destruction results in the accumulation in the oceans of vast

quantities of small particles of rock, which settle down in the quiet waters into horizontal layers and beds, which are gradually consolidated and cemented together into rocks.

Sandstone, as its name implies, is a rock composed of grains of sand. The grains are usually quartz and may be large or small. If they are very small, it is proof that they have been transported by streams for long distances, or have in other ways worn each other down. If they have not been transported far, there may be fragments of considerable size in the rock. If such rock is composed of angular fragments, it is called *breccia;* if it is made up of rounded pebbles, it is called *conglomerate.* In most sandstones the particles are small and sometimes so minute that the individual grains are scarcely visible and the rock then resembles felsite. A good hand lens, however, will reveal the grains.

The cement which binds the grains into a rock varies. It may be deposited silica, or calcite, or an iron oxide; or, at times, a clay.

The color of the rock depends chiefly on the character of the cement. If it is hematite the rock is red; if limonite, it is yellow. In the great exposures of sandstones in the Grand Canyon and elsewhere, these colors predominate. Many sandstones, whose cement is not an iron oxide, are gray or nearly white.

Shale. Rains wash down into the streams multitudes of tiny particles of weathered rock. These are not only the sand grains, but also mica and feldspar, the latter more or less altered to kaolin. As these descend to the ocean they are ground finer and finer until on reaching still water they sink to the bottom and form beds of mud, or silt, or clay. These materials are slowly consolidated and cemented in layers into the rock, called shale. So fine are the particles that they are rarely visible even with the aid of a lens. If quartz is present it is detected by the greater hardness of the rock, which usually is very soft. As the percentage of quartz increases the shales grade into sandstones.

Shales vary much in color, but usually they are gray. The presence of iron oxides imparts a red or a yellow color, the same as in sandstone, while other impurities may make the rock green or black.

Shales are very plentiful rocks in many sections, and there are great exposures of them in both the Eastern and Western states.

Limestone has a very different origin from sandstone. Instead of being made up of fragments of the older rocks, carbonate of lime or calcite has been separated from the sea water by minute living organisms and has been deposited on the ocean bed where it has been consolidated into a fine-grained rock. Many limestones contain the fossil remains

of these organisms and their many forms introduce the study of paleontology in a most fascinating way. Some of the most plentiful of the fossiliferous limestones are those made up of the shells of mollusks and gastropods, or of crinoids or corals.

Limestone is most commonly of a dull gray color, thus contrasting with the bright reds and yellows of many sandstones. Many brighter colors are, however, occasionally seen. It is soft enough to be readily scratched with a knife and, when pure, is soluble with bubbling in any cold acid such as vinegar or lemon juice, or the acids of the laboratory. Impurities such as sand or clay will remain as a residue.

Dolomitic limestone is a common variety. It is composed largely or completely of the mineral dolomite, instead of calcite, and is distinguished by the fact that the acid must be heated before the rock will completely dissolve. It is a carbonate of both calcium and magnesium.

Limestone occurs in beds often of great thickness, the horizontal or tilted layers being striking features in the landscape, or the rock may be composed of many thin layers thus producing an attractive, banded structure.

Oolite or *oolitic* limestone, is a variety composed of countless multitudes of spherical concretions of calcite. Oolite is described further on page 93.

Chalk is a very fine-grained and soft limestone, composed of shells of very minute animals known as foraminifera. See further on page 150.

Travertine is the name given to the limestone deposited in large quantities by springs or rivers, as at Tivoli, Italy. The slower deposit by cold waters in caves produces the *stalactites* and *stalagmites* described on page 97. The more compact stalagmitic formations are called *Mexican-onyx* and are often beautifully banded or mottled by the staining of iron oxides.

Calcareous tufa is a less compact limestone redeposited on leaves, twigs, moss and other vegetation.

Impure limestones are named from the foreign material they contain, thus *argillaceous limestone* contains much clay, *arenaceous-limestone* is full of sand, *cherty limestone* contains sharp fragments of chert.

The economic importance of limestone is very great. It is used in vast quantities as a building stone; it is the source of lime; is used in cement-making and as a flux in smelting iron ores.

Marl is a loose, earthy deposit of limestone and clay. *Sandy marl* contains also sand; *shell marl* contains shells; *greensand marl* contains much glauconite.

Conglomerate is a rock composed of *round* fragments of any kind of rock cemented into a solid mass. The commonest types of conglomerate are those in which quartz pebbles are cemented by sand, clay or calcareous material. The pebbles may be from a fraction of an inch up to a foot or more in diameter. The conglomerates are named for the material which is most abundant in them; the commonest types are *quartz conglomerate* and *limestone conglomerate.*

Breccia is the same as conglomerate except that instead of rounded pebbles it is composed of *angular* fragments.

Rocks occur in which both round pebbles and angular fragments occur. These are called **conglomerate breccia,** figure 256.

Figure 256. Conglomerate-Breccia, "Calico Marble," Point of Rocks, Maryland

III. METAMORPHIC ROCKS

Metamorphic rocks are the results of heat, pressure and chemical action on igneous and sedimentary rocks. Most of those which were formerly igneous rocks differ most strikingly in showing a banded structure. Many of those formed from sedimentary rocks, which usually show a banded structure, differ chiefly in exhibiting a crystalline structure.

The following table shows clearly the usual origin of the leading metamorphic rocks:

(a) **Original Rock, Igneous:**	**Resulting Metamorphic Rock:**
Granite	Gneiss
Felsite or tuff	Slate or schist
Basalt or dolerite	Hornblende-schist, talc-schist, serpentine
(b) **Original Rock, Sedimentary**	**Resulting Metamorphic Rock:**
Limestone	Marble
Sandstone	Quartzite
Shale	Slate

Gneiss is commonly a metamorphosed granite and is composed of the same minerals, quartz and feldspar, with either mica or hornblende or both. There are, however, gneisses formed from conglomerates or other sedimentary rocks. A distinct banded structure is usually a prominent feature of gneiss, but this is sometimes on so large a scale that hand-size specimens do not show it, or at times no banding is visible even in large masses. A hornblende-granite will yield a *hornblende-gneiss*, a biotite-granite produces a *biotite-gneiss*, figure 257. Gneiss is the commonest of the metamorphic rocks and is usually of a light color.

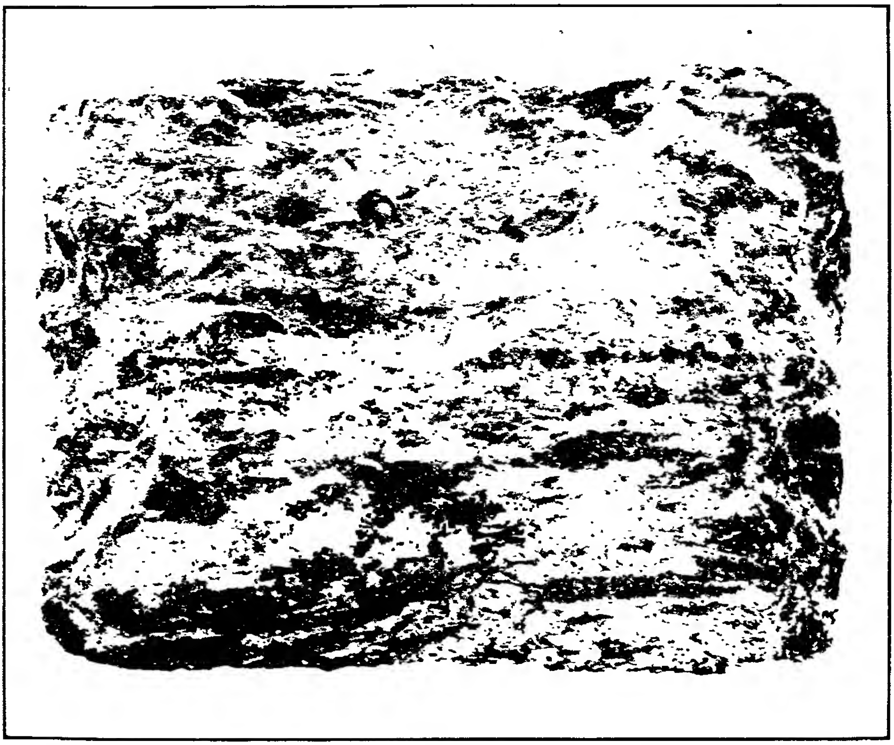


Figure 257. Biotite-Gneiss, Showing Banded Structure, Uxbridge, Massachusetts

Mica-schist differs from gneiss chiefly in the absence of feldspar; it is, therefore, usually composed of quartz and mica. The mica is either muscovite or biotite and it is the most abundant ingredient, its plates being arranged in parallel planes which produce what is called a "schistose structure." Its color is usually gray, if muscovite is its chief mineral, or black if biotite predominates. Next to gneiss, mica-schist is the commonest of the metamorphic rocks.

Other Schists. There are various other schists which are chiefly produced by the change of those igneous rocks rich in iron and magnesium, such as peridotite, pyroxenite, gabbro or dolerite.

Hornblende-schist is probably the commonest of these rocks. In it amphibole of one variety or another, is the most abundant mineral. The color is usually dark green to black and the grain of the rock is either fine or coarse. In the coarser varieties the hornblende may be seen with the naked eye as blades or long needles with distinct cleavage.

In the finer-grained varieties of hornblende-schist the blades or needles can be seen only by the aid of a lens and usually the rock is less schistose in structure, grading into a compact mass, to which the name *amphibolite* is often given, though this name is not infrequently applied to any hornblende-schist.

Hornblende-schist is heavy and hard enough so that it is scratched with difficulty by a knife.

Chlorite-schist, is a rock composed chiefly of closely compacted, minute scales of chlorite, usually of a dull, grayish-green color and soft enough to be easily scratched with a knife. It is a widely distributed rock.

Greenstone is a compact variety of chlorite-schist.

Talc-schist is a schistose rock of a pearly luster and greasy feel due to its abundance of talc. This may be in coarse foliated aggregates, or in fine scales and because of its softness the rock may be scratched with the finger nail. As the rock becomes less pure and more compact it passes into *steatite* or *soapstone.*

Quartzite is metamorphosed sandstone. It is an exceptionally hard, firm and compact rock, breaking with a conchoidal or splintery fracture. This method of breaking is due to the fact that in the alteration of the original rock its grains have been firmly cemented: so that while sandstone breaks through the cement and not through the individual grains, in quartzite the fracture is straight through grains and cement alike. This fact makes it easy to distinguish between these two rocks.

Typical quartzite is a pure quartz rock whose color would naturally be white, but there are, of course, many impurities, usually minerals of microscopic sizes, which impart various colors, such as red, pink, gray or brown. Mica may be present in considerable quantity and if so the rock grades into a mica-schist.

Quartzite is a very common rock and, because of its great hardness, and insolubility in water, it resists weathering and is, therefore, often a prominent feature in the landscape, appearing in castellated or cathedral-like spires, or bold cliffs, or ledges.

Slate is a soft, dense rock which cleaves readily into thin plates. Its mineral grains, like those of the parent rock, shale, are so fine that they cannot be distinguished even with a lens.

The parting of shale is parallel with the natural stratification, but the cleavage so characteristic of slate has no relation to the original stratification, but is due to the great pressure which altered the shale as well as the cleavage of the minerals making up the slate. As these are all microscopic the beginner need not bother with them. The color of slate is commonly gray or black, but may be red, green, brown, yellow.

Slate is used as roofing tiles, in laboratory tables and many minor structural uses.

Marble is limestone metamorphosed by heat and pressure into a crystalline rock. It may be either fine-grained, as in the Carrara and Vermont marbles, or coarse-grained, as in those of Georgia. Typical calcite marble is pure white, but in many localities a little graphite shows itself as black veins, or the presence of iron oxide gives red and yellow colors, while a green mottling is due to chlorite. Pure marble, of course, has the composition and properties of calcite, see page 149.

Dolomite marble cannot be distinguished at sight from calcite marble. Lee, Massachussetts produces a typical fine-grained variety and Tuckahoe, New York a coarse-grained.

In the marble trade many rocks are sold as "marble" which, from a geological standpoint, are not true marbles. Thus the very widely used "Tennessee Marbles" are really not metamorphic rocks, but limestones. Any rock which is not classed as a "granite" is termed "marble" by the trade if it takes a good polish and can be produced in large blocks. Many limestones containing fossil corals, crinoid stems and shells of many kinds are sold as "marble." Italy, France, Greece and many other countries besides the United States are large producers.

Serpentine is described on page 242.

APPENDIX I

IDENTIFICATION OF MINERALS

Steps in Determining Minerals

1st. Observe the *luster* and decide whether the specimen is *metallic* or *non-metallic.*

2d. Determine the *hardness,* as explained in Chapter 5.

3d. Observe the *color* and, if the luster is metallic, test the streak. With the aid of the table on page 270 you should then be able to decide whether your specimen is one of the minerals included in this list.

4th. If your specimen does not have metallic luster, your next step, after determining its hardness, will be to decide in which one of the *color groups* it belongs.

5th. Next observe its color more minutely and decide which one of the colors under the general heading you selected, most accurately fits your specimen.

6th. Compare its properties with those mentioned under "other characteristics" and you will probably find that your specimen tallies with one of the minerals there described. If you are still in doubt, turn to the further description of the mineral you think it is and you will come to a definite conclusion, which will almost certainly be correct.

Points to be Noted

(a) *Hardness.* It is quite possible that the beginner may not be able to determine the hardness accurately unless there are sharp points and smooth surfaces on the specimen. Do not be discouraged. Test it, as suggested on page 32, with your finger nail, a cent, your knife blade and a quartz crystal, and you will get a good rough idea of its hardness. Then use such minerals in the regular scale of hardness as you find necessary.

(b) *Color.* Even if you do not succeed in accurately determining the hardness, it will not be a hopeless task to check up your specimen with all of the minerals in several of the groups of the same color. For example: if you decide that its general color is blue and you are in doubt as to whether its hardness is 3 or 4, run through the descriptions of

ALL of the minerals under "Color Green or Blue" in the sections headed "Hardness 3. to 3.75" and "Hardness 4. to 4.75."

(c) *Specific Gravity* ("G") is noted for a few minerals, not with the idea that you will determine it with accuracy, but to call your attention to minerals which are notably heavy.

(d) *Other Characteristics* noted, such as crystal form, cleavage, structure and other distinctive peculiarities, will greatly aid you. You will be familiar with all of these if you have studied Chapters 1 to 19. Bear in mind that minerals vary greatly and that your specimen may have a different color or form or in a number of ways be unlike the descriptions given in the table and still be the mineral to which the table leads you. This table is by no means complete, but it does contain the large majority of the minerals you are most likely to meet, and in their most important variations.

KEY TO DETERMINATION OF MINERALS

DIVISION I. MINERALS WITH METALLIC OR SUB-METALLIC LUSTER

DIVISION II. MINERALS WITHOUT METALLIC LUSTER

I. MINERALS WITH METALLIC OR SUB-METALLIC LUSTER

Hardness	Color	Streak	Mineral	Page
(a) Hardness: 1. to 1.75				
1. to 1.5	Pure lead-gray	Bluish-gray on paper; greenish-gray on porcelain	**Molybdenite**	192
1. to 2.	Iron-black to dark steel-gray	Black, shining	**Graphite**	162
(b) Hardness: 2. to 2.75				
2.	Lead-gray	Lead-gray	**Stibnite**	137
2. to 2.5	Iron-black or dark gray	black	**Pyrolusite**	189
2. to 2.5	Blackish lead-gray	Blackish lead-gray shining	**Argentite**	196
2.5 to 2.75	Pure lead-gray	Pure lead-gray	**Galena**	184
2.5 to 3.	Blackish lead-gray	Blackish lead-gray	**Chalcocite**	170
2.5 to 3.	Golden-yellow	Golden-yellow	**Gold**	174
2.5 to 3.	Silver-white	Silver-white	**Silver**	195
2.5 to 3.	Copper-red	Copper-red, shining	**Copper**	168
(c) Hardness: 3. to 3.75				
2.5 to 3.	Blackish lead-gray,	Blackish lead-gray	**Chalcocite**	170
2.5 to 3.	Golden-yellow	Golden-yellow	**Gold**	174
2.5 to 3.	Silver-white	Silver-white	**Silver**	195
2.5 to 3.	Copper-red	Copper-red, shining	**Copper**	168
3.	Reddish pinchbeck-brown	Pale grayish-black	**Bornite**	170
3. to 4.	Flint-gray to iron-Black	Same as color	**Tetrahedrite**	171
3.5	Tin-white	Tin-white	**Antimony**	137
3. to 3.5	Tin-white	Tin-white	**Arsenic**	138
3.5 to 4.	Brass-yellow	Greenish-black	**Chalcopyrite**	169
3.5 to 4.	Light bronze-yellow	Light bronze-brown	**Pentlandite**	193
3.5 to 4.5	Reddish bronze-yellow	Dark grayish-black	**Pyrrhotite**	179

Hardness	Color	Streak	Mineral	Page
(d) Hardness: 4. to 4.75				
3. to 4.	Flint-gray to iron-black	Same as color	**Tetrahedrite**	171
3.5 to 4.	Brass-yellow	Greenish-black	**Chalcopyrite**	169
3.5 to 4.	Light bronze-yellow	Light bronze-brown	**Pentlandite**	193
3.5 to 4.5	Reddish bronze-yellow	Dark grayish-black	**Pyrrhotite**	179
4.	Dark steel-gray to iron-black	Reddish-brown to nearly black	**Manganite**	106
(e) Hardness: 5. to 6.5				
5. to 5.5	Pale copper-red	Pale brownish-black	**Niccolite**	193
5. to 5.5	Black	Black	**Wolframite**	205
5. to 5.5	Brownish-red to brownish-black	Yellowish-brown, greenish gray	**Huebnerite**	205
5.5	Iron-black	Brown	**Chromite**	166
5. to 6.	Iron-black	Black to reddish-brown	**Ilmenite**	203
5.5 to 6.5	Dark steel-gray to iron-black	Cherry-red or reddish-brown	**Hematite**	179
5.5 to 6.5	Iron-black	Black	**Magnetite**	182
5.5 to 6.5	Iron-black	Reddish-brown or black	**Franklinite**	210
5.5 to 6.5	Silver-white to steel-gray	Dark grayish-black	**Arsenopyrite**	139
6. to 6.5	Pale brass-yellow	Greenish-black or brownish-black	**Pyrite**	178
6. to 6.5	Pale bronze-yellow	Grayish or brownish-black	**Marcasite**	178
6. to 6.5	Brown or reddish-black	Pale brown	**Rutile**	202

II. MINERALS WITHOUT METALLIC LUSTER

Hardness	Color	Other Characteristics	Mineral	Page
(a) Hardness 1. to 1.75:				
Color Yellow:				
1.	Ocher-yellow	Dull, earthy, soils fingers	**Yellow ocher**	182
1. to 2.	Cream-yellow	Massive or foliated	**Pyrophyllite**	136
1. to 3.	Yellow of various shades	Earthy or pisolitic	**Bauxite**	131
1.5 to 2.	Lemon-yellow	Masses dull, cleavages bright, pearly luster	**Orpiment**	138
1.5 to 2.	Pale yellow	Massive or fibrous	**Gypsum**	153
1.5 to 2.5	Sulphur-yellow	Crystals have typical sulphur yellow color; masses may be greenish-gray, brown, red	**Sulphur**	200
Color Red:				
1. to 3.	Brownish-red	Massive or pisolitic, dull	**Bauxite**	131
1.5 to 2.	Flesh-red	Massive, fine granular	**Gypsum**	153
1.	Brownish-red	Dull, earthy, soils fingers	**Red ocher**	180
1.5 to 2.	Aurora-red	Gorgeous color, brittle	**Realgar**	138
Color Brown:				
1. to 3.	Brown of various shades	Massive or pisolitic, dull	**Bauxite**	131
1.5 to 2.	Reddish-brown	Massive, fine granular	**Gypsum**	153
Color Black or Gray:				
1. to 3.	Gray	Massive or pisolitic, dull	**Bauxite**	131
1.5 to 2.	Black or gray	Massive, fine granular	**Gypsum**	153
1. to 1.5	Gray	Massive or foliated	**Talc**	242
1. to 2.	Gray	Massive or foliated	**Pyrophyllite**	136

Hardness	Color	Other Characteristics	Mineral	Page

Color White:

1. to 3.	White of many tints	Massive or pisolitic	**Bauxite**	131
1.5 to 2.	Snow-white, bluish	Massive, fine granular	**Gypsum**	153
1. to 2.	White, various tints	Massive or foliated	**Pyrophyllite**	136
1. to 1.5	White, various tints	Massive or foliated	**Talc**	242
1.	Snow-white	Fibrous, fluffy	**Ulexite**	145

Color Green:

1. to 1.5	Green, various tints	Foliated, sectile	**Talc**	242
1. to 2.	Brownish-green	Massive or foliated	**Pyrophyllite**	136
1. to 2.	Blackish-green or olive-green	Flaky-granular masses	**Prochlorite**	232

(b) Hardness 2. to 2.75:
Color Yellow:

1. to 2.	Cream-yellow	Massive or foliated	**Pyrophyllite**	136
1.5 to 2.	Lemon-yellow	Masses dull, cleavages bright, luster pearly	**Orpiment**	138
1.5 to 2.5	Sulphur-yellow	Crackles in hand	**Sulphur**	200
2.5 to 3.	Brownish-yellow	Micaceous cleavage	**Phlogopite**	230
2.75 to 3.	Yellow, various	Crystals six-sided	**Vanadinite**	207
2.75 to 3.	Lemon to orange	Crystals four-sided	**Wulfenite**	192
2.5 to 4.	Grayish-yellow	Granular-micaceous	**Lepidolite**	230
2.5 to 5.5	Greenish-yellow	Massive, oily luster	**Serpentine**	242

Color Red:

1.5 to 2.	Aurora-red	Gorgeous color, brittle	**Realgar**	138
2. to 2.5	Cochineal-red	Streak scarlet; G. 8.0	**Cinnabar**	191
2. to 2.5	Scarlet-red	Streak scarlet; G. 5.6	**Proustite**	197
2.5 to 3.	Hyacinth-red	Streak orange; G. 6.0	**Crocoite**	167
2.5 to 3.5	Dark brownish-red	Vitreous luster; G. 4.5; streak white	**Barite**	139

Hardness	Color	Other Characteristics	Mineral	Page
2.75 to 3.0	Bright red, many shades	Crystals six-sided; streak nearly white	**Vanadinite**	207
2.75 to 3.0	Bright orange-red	Crystals four-sided; streak nearly white	**Wulfenite**	192
2.5 to 5.5	Dull brownish-red	Massive, oily luster	**Serpentine**	242

Color Brown:

2. to 2.5	Hair-brown	Mica, found with quartz and feldspar	**Muscovite**	229
2.5 to 3.	Yellowish-brown, often with coppery reflections	Mica, found in limestone or serpentine	**Phlogopite**	230
2.75 to 3.	Grayish-brown	Crystals six-sided, brittle; no cleavage	**Vanadinite**	207

Color Black or Gray:

1. to 2.	Light gray	Massive or foliated	**Pyrophyllite**	136
2. to 2.5	Dark gray to black	Massive or oolitic	**Collophanite**	153
2. to 2.5	Dull gray	Massive, clay-like	**Kaolinite**	133
2. to 2.5	Grayish-white	Micaceous cleavage	**Muscovite**	229
2.5 to 3.	Black or dark brown	Micaceous cleavage	**Biotite**	230
2.5 to 4.	Pale gray	Granular-micaceous	**Lepidolite**	230
2.5	Black or grayish-black	Streak purplish-red; luster metallic-adamantine	**Pyrargyrite**	197
2.75 to 3.	Yellowish-gray or grayish-white	Crystals four-sided; G. 7.0	**Wulfenite**	192

Color White, or Colorless:

1. to 2.	Grayish-white	Massive or foliated	**Pyrophyllite**	136
2.	Colorless	Sectile, cleavage plates; or crystals, figures 187, 188	**Selenite**	153
2. to 2.5	Snow-white or grayish-white	Massive, clay-like	**Kaolinite**	133
2. to 2.5	Colorless, altering to snow-white	Dissolves in water	**Borax**	144

Hardness	Color	Other Characteristics	Mineral	Page
2. to 2.5	Dull white or yellowish- or grayish-white	Massive; pebbles or oolitic	**Collophanite**	153
2.5	Colorless to snow-white	Massive or showing nearly cubical cleavage	**Cryolite**	198
2.5	Grayish- or bluish-white	Easy basal cleavage; sectile; luster pearly	**Brucite**	188
2.5 to 3.5	Colorless, snow-white or yellowish-white	Granular-massive or cleavable; G. 4.5	**Barite**	139
2.75 to 3.	Colorless or white of various tints	Luster adamantine or vitreous or greasy; very heavy; G. 6.3	**Anglesite**	185

Color Green or Blue:

1. to 2.	Blackish-green to grass-green	Granular-massive or in worm-like crystals	**Prochlorite**	232
2. to 2.5	Dark bluish-green or pale grayish-green	Six-sided plates or scaly-granular	**Clinochlore**	232
2. to 2.5	Emerald-green when viewed laterally	Micaceous cleavage	**Muscovite**	229
2.5	Pale grayish-blue	Easy basal cleavage; sectile; pearly luster	**Brucite**	188
2.5	Prussian-blue in colorless mass	Saline taste; cubic cleavage	**Halite**	198
2. to 3.	Apple-green	Amorphous; very friable	**Garnierite**	193
2. to 4.	Bluish- or grayish-green, turquois-blue	Amorphous or botryoidal; friable	**Chrysocolla**	173
2.5 to 3.5	White or colorless, tinted pale blue	Tabular crystals	**Barite**	139
2.5 to 4.	Lavender, lilac or violet	Granular-micaceous	**Lepidolite**	230
2.5 to 5.5	Leek- or blackish-green	Massive; oily luster	**Serpentine**	242

(c) Hardness 3. to 3.75:
Color Yellow:

2.5 to 3.	Brownish-yellow	Micaceous cleavage	**Phlogopite**	230
2.5 to 4.	Grayish-yellow	Granular-micaceous	**Lepidolite**	230
2.5 to 5.5	Greenish-yellow	Massive; oily luster	**Serpentine**	242

Hardness	Color	Other Characteristics	Mineral	Page
2.75 to 3.	Yellow, various	Crystals six-sided	**Vanadinite**	207
2.75 to 3.	Lemon to orange	Crystals four-sided	**Wulfenite**	192
3.	Light yellow	Crystalline or with cleavage into rhombs	**Calcite**	146
3.5	Brownish-yellow	Drusy or stout crystals	**Descloiz-ite**	207
3.5 to 4.	Cream- to wine-yellow	Coarse-fibrous, or in six-sided crystals; no cleavage	**Aragonite**	150
3.5 to 4.	Pale wine-yellow to nearly white	Radiated-crystalline masses, or crystals	**Strontian-ite**	199
3.5 to 4.	Brownish-yellow	Radiated or sheaf-like	**Stilbite**	247
3.5 to 4.	Brownish-yellow	Granular, or showing distinct dodecahedral cleavage	**Sphalerite**	208

Color Red:

2.5 to 3.	Hyacinth-red	Streak orange; G. 6.0	**Crocoite**	167
2.75 to 3.	Bright red, many shades	Crystals six-sided; streak nearly white	**Vanadinite**	207
2.75 to 3.	Bright orange-red	Crystals four-sided; streak nearly white	**Wulfenite**	192
2.5 to 3.5	Dark reddish-brown	Vitreous luster; G. 4.5; streak white	**Barite**	139
2.5 to 5.5	Dull brownish-red	Massive; oily luster	**Serpentine**	242
3.	Various shades of red	Crystalline, or with cleavage into rhombs	**Calcite**	146
3. to 3.5	Brownish- to yellowish-red	Usually in tabular crystals or cleavages	**Celestite**	199
3.5	Brownish-red to scarlet	Stout crystals or drusy	**Descloiz-ite**	207
3.5 to 4.	Brick-red	Coffin-shaped crystals; luster vitreous and pearly	**Heulandite**	246
3.5 to 4.	Brick-red	Radiated or sheaf-like	**Stilbite**	247
3.5 to 4.	White, tinted pink	Very fine-granular	**Alunite**	195
3.5 to 4.	Ruby-red to cochineal-red	Streak brownish-red, shining; G. 6.0	**Cuprite**	171

Hardness	Color	Other Characteristics	Mineral	Page
3.5 to 4.5	Rose-pink to brownish-red	Crystalline or in rhombs or scalenohedrons	**Rhodochrosite**	190

Color Brown:

Hardness	Color	Other Characteristics	Mineral	Page
1. to 3.	Brown, various shades	Massive or pisolitic; dull	**Bauxite**	131
2.5 to 3.	Yellowish-brown, often with coppery reflections	Mica, found in limestone or serpentine	**Phlogopite**	230
2.5 to 3.5	Brown, various shades	Granular masses; G. 4.5	**Barite**	139
2.75 to 3.	Grayish-brown	Crystals six-sided; brittle; no cleavage	**Vanadinite**	207
3.	Brown, various shades	Crystalline or with cleavage into rhombs	**Calcite**	146
3.5	Light to blackish-brown	Stout crystals or drusy	**Descloizite**	207
3.5 to 4.	Pale to dark brown	Crystalline, or with cleavage into rhombs	**Siderite**	183
3.5 to 4.	Light to blackish-brown	Granular, or showing dodecahedral cleavage	**Sphalerite**	208
3.5 to 4.	Yellowish-brown	Radiated or sheaf-like	**Stilbite**	247

Color Black or Gray:

Hardness	Color	Other Characteristics	Mineral	Page
2.5 to 3.5	Light to dark gray	Granular masses; G. 4.5	**Barite**	139
2.5 to 4.	Pale gray	Granular-micaceous	**Lepidolite**	230
2.75 to 3.	Yellowish-gray or grayish-white	Crystals four-sided; G. 7.0	**Wulfenite**	192
2.75 to 3.	Dull gray	Fine-granular masses; G. 6.3	**Anglesite**	185
3.	Various shades of gray	Granular masses; fizz with acid	**Calcite, Limestone**	146
3. to 3.5	Light gray	Granular masses	**Anhydrite**	154
3. to 3.5	Light to dark gray	Fine-granular masses, greasy-adamantine luster; or reticulated or slender crystals	**Cerussite**	185
3.5	Grayish-black	Stout crystals or drusy	**Descloizite**	207

Hardness	Color	Other Characteristics	Mineral	Page
3.5 to 4.	Various shades of gray	Granular masses; dissolves only in hot acid	**Dolomite-Limestone**	187
3.5 to 4.	Light gray	Very fine-granular	**Alunite**	195
3.5 to 4.	Gray grading to white and black	Fine to coarse-granular	**Sphalerite**	208

Color White, or Colorless:

Hardness	Color	Other Characteristics	Mineral	Page
2.5 to 3.5	Colorless, snow-white or yellowish-white	Granular-massive or cleavable; G. 4.5	**Barite**	139
2.75 to 3.	Colorless or white of various tints	Luster adamantine or vitreous or greasy; very heavy, G. 6.3	**Anglesite**	185
3.	Various shades	Crystalline or with cleavage into rhombs, or in crystals	**Calcite**	146
3.	Colorless	Cleaves into plates resembling selenite; soluble in water	**Kernite**	145
3. to 3.5	Snow-, grayish- or bluish-white	Fine-granular masses	**Anhydrite**	154
3. to 3.5	Crystals colorless, masses snow-white, grayish-, bluish-white	Best distinguished from barite by flame test	**Celestite**	199
3. to 3.5	Snow-white to grayish	Acicular or reticulated crystals, or masses with greasy-adamantine luster	**Cerussite**	185
3. to 3.75	Yellowish- or grayish-white	Columnar or in six-sided double pyramids	**Witherite**	141
3.5 to 4.	Yellowish- or grayish-white	Granular masses; resinous-adamantine luster	**Sphalerite**	208
3.5 to 4.	Snow-white or various other shades	Coarse- or fine-granular, or rhombohedral crystals or cleavages	**Dolomite**	187
3.5 to 4.	White of many shades, or colorless crystals	Granular-fibrous masses, or steep, pyramidal crystals	**Aragonite**	150
3.5 to 4.	White of many shades	Compact-massive, fine- or coarse-crystalline, or rhombic cleavages	**Magnesite**	187

Hardness	Color	Other Characteristics	Mineral	Page
3.5 to 4.	Yellowish-, grayish- or greenish-white	Columnar-fibrous masses, or steep-pyramidal crystals	**Strontianite**	199
3.5 to 4.	Crystals colorless to slightly reddish-white	Coffin-shaped or rounded crystals; brilliant luster	**Heulandite**	246
3.5 to 4.	Snow-white, grayish- or brownish-white	Radiated or sheaf-like	**Stilbite**	247
3.5 to 4.	Grayish- or pinkish-white	Fine-granular masses	**Alunite**	195

Color Green or Blue:

Hardness	Color	Other Characteristics	Mineral	Page
2. to 3.	Apple-green	Amorphous; very friable	**Garnierite**	193
2. to 4.	Bluish-green	Amorphous or botryoidal; friable	**Chrysocolla**	173
2.5 to 3.5	Colorless tinted green or blue	Tabular crystals	**Barite**	139
2.5 to 5.5	Leek or blackish-green	Massive; oily luster	**Serpentine**	242
3.	Green or blue of various shades	Cleavable masses, also many other types	**Calcite**	146
3. to 3.5	White tinted light blue	Fine-granular	**Anhydrite**	154
3. to 3.5	Pale grayish-blue	Fibrous or granular	**Celestite**	199
3.5 to 4.	White tinted by blue or green	Fibrous or massive	**Aragonite**	150
3.5 to 4.	Blue of many shades	Crystals and masses	**Azurite**	172
3.5 to 4.	Light or dark green	Tufted, or in masses with concentric banding	**Malachite**	172

(d) Hardness 4. to 4.75:
Color Yellow:

Hardness	Color	Other Characteristics	Mineral	Page
2.5 to 4.	Grayish-yellow	Granular-micaceous	**Lepidolite**	230
2.5 to 5.5	Greenish-yellow	Massive; oily luster	**Serpentine**	242
3.5 to 4.	Grayish-yellow	Crystals, or granular masses; resinous-adamantine luster	**Sphalerite**	208
3.5 to 4.	Pale wine-yellow to nearly white	Radiated-crystalline masses, or crystals	**Strontianite**	199

Hardness	Color	Other Characteristics	Mineral	Page
3.5 to 4.	Cream- or wine-yellow	Coarse-fibrous, or six-sided crystals; no cleavage	Aragonite	150
3.5 to 4.	Brownish-yellow	Radiated or sheaf-like	Stilbite	247
4.	Wine-yellow	Isometric crystals, octahedral cleavages, or granular masses	Fluorite	151
4.5 to 5.	Wine-yellow	Transparent crystals	Apatite	152
4.5 to 5.	Pale to deep yellow	Double four-sided pyramidal crystals, or masses	Scheelite	205

Color Red:

Hardness	Color	Other Characteristics	Mineral	Page
2.5 to 5.5	Dull brownish-red	Massive; oily luster	Serpentine	242
3.5 to 4.	Brownish-red	Small, rounded crystals	Sphalerite "ruby blende"	208
3.5 to 4.	Ruby- to cochineal-red	Streak brownish-red, shining; G. 6.0	Cuprite	171
3.5 to 4.	Brick-red	Coffin-shaped crystals; luster vitreous and pearly	Heulandite	246
3.5 to 4.	White, tinted pink	Very fine-granular	Alunite	195
3.5 to 4.5	Rose-pink to brownish-red	Crystalline, or in rhombs or scalenohedrons	Rhodochrosite	190
4. to 5.	Flesh-red	Crystals are rhombs	Chabazite, "Acadialite"	247
4. to 4.5	Rich blood-red	Streak orange-yellow	Zincite	212
4.5 to 5.	Brownish-red	In large six-sided prisms	Apatite	152
4.5 to 5.	Colorless with rose-pink tint	In tetragonal crystals (figures 40 and 252)	Apophyllite	250

Color Brown:

Hardness	Color	Other Characteristics	Mineral	Page
3.5 to 4.	Light to blackish-brown	Granular or showing dodecahedral cleavage	Sphalerite	208
3.5 to 4.	Pale to dark brown	Crystalline, or with cleavage into rhombs	Siderite	183
3.5 to 4.	Yellowish-brown	Radiated or sheaf-like	Stilbite	247

Hardness	Color	Other Characteristics	Mineral	Page
4.	Light to dark brown	Cubical crystals; octahedral cleavage	**Fluorite**	151
4.5 to 5.	Reddish-brown	In large six-sided prisms	**Apatite**	152

Color Black or Gray:

Hardness	Color	Other Characteristics	Mineral	Page
2.5 to 4.	Pale gray	Granular-micaceous	**Lepidolite**	230
3.5 to 4.	Gray, grading to white and black	Fine- to coarse-granular	**Sphalerite**	208
3.5 to 4.	Various shades of gray	Granular masses; dissolves only in hot acid	**Dolomite-Limestone**	187
3.5 to 4.	Purplish-gray	Twins resembling six-sided prisms	**Aragonite**	150
3.5 to 4.	Pale gray	Very fine-granular	**Alunite**	195
4.5 to 5.	Light gray	In tetragonal crystals (figures 40 and 252)	**Apophyllite**	250
4.5 to 5.	Light to dark gray	In large six-sided prisms	**Apatite**	152

Color White, or Colorless:

Hardness	Color	Other Characteristics	Mineral	Page
3.5 to 4.	Snow-white or tinted gray or yellow	Coarse to fine-crystalline, or in rhombohedral crystals	**Dolomite**	187
3.5 to 4.	Snow-white, or various tints	Crystals twinned, appearing hexagonal, radiated, fibrous, crystalline	**Aragonite**	150
3.5 to 4.	Yellowish-white or brownish-white	Radiated or sheaf-like	**Stilbite**	247
3.5 to 4.	Snow-white, yellowish and other tints	Coffin-shaped crystals; luster vitreous and pearly	**Heulandite**	246
3.5 to 4.	Grayish- or pinkish-white	Very fine-granular	**Alunite**	195
3.5 to 4.5	Snow-white or tinted gray or yellow	Compact, crystalline or in cleavage rhombs	**Magnesite**	187
4.	Colorless, or various shades of white	Cubical crystals, octahedral cleavages, or granular-crystalline masses	**Fluorite**	151

Hardness	Color	Other Characteristics	Mineral	Page
4. to 4.5	Colorless, or yellowish- to milk-white	Complex crystals, or cleavage masses	**Colemanite**	145
4. to 5.	Colorless, snow-white or reddish-white	Crystals are rhombs	**Chabazite**	247
4. to 7.25	Yellowish- to snow-white	Coarsely-bladed	**Kyanite**	134
4.5 to 5.	Colorless, or white of various tints	Crystals usually in odd cockscomb groups, often drusy in cavities	**Calamine**	209
4.5 to 5.	Colorless, or tinted pink, green or blue	In tetragonal crystals (figures 40 and 252)	**Apophyllite**	250
4.5 to 5.	Colorless, or white of various shades	Colorless, transparent, crystals, usually tabular, with many faces; when in masses, nearly opaque	**Apatite**	152
4.5 to 5.	White either milky or of various shades	Double four-sided pyramidal crystals, or masses	**Scheelite**	205

Color Green or Blue:

2. to 4.	Bluish-green to turquois-blue	Amorphous or botryoidal; friable	**Chrysocolla**	173
2.5 to 4.	Lavender, violet, lilac	Granular-micaceous	**Lepidolite**	230
2.5 to 5.5	Leek- or blackish-green	Massive; oily luster	**Serpentine**	242
3.5 to 4.	Pale greenish or blue	Fibrous or massive	**Aragonite**	150
3.5 to 4.	Pale asparagus-green	Radiated, crystalline masses, or crystals	**Strontianite**	199
3.5 to 4.	Light or dark green	Tufted, or in masses with concentric banding	**Malachite**	172
3.5 to 4.	Blue of many shades	Crystals and masses	**Azurite**	172
4.	Many shades of green and blue	Cubical crystals, octahedral cleavages, granular-crystalline masses	**Fluorite**	151
4. to 7.25	Sapphire-blue to green of many shades	Coarsely-bladed	**Kyanite**	134
4.5 to 5.	Pale blue or green tints in white	Crystals usually in odd cockscomb groups, often drusy in cavities	**Calamine**	209

Hardness	Color	Other Characteristics	Mineral	Page
4.5 to 5.	Pale blue or green tints in white	In tetragonal crystals (figures 40 and 252)	**Apophyllite**	250
4.5 to 5.	Various shades of blue and green	In hexagonal prisms, often large, or in showy masses	**Apatite**	152
4.5 to 5.	Dull shades mostly greenish-white	Double four-sided, pyramidal crystals, or masses	**Scheelite**	205

(e) Hardness 5. to 5.75:
Color Yellow:

2.5 to 5.5	Greenish-yellow	Massive; oily luster	**Serpentine**	242
4.5 to 5.	Pale to deep yellow	Double four-sided pyramidal crystals, or masses	**Scheelite**	205
5.	Turkey-fat yellow	Mammillary masses	**Smithsonite**	209
5. to 5.5	Pale yellowish	Usually in groups of crystals	**Datolite**	250
5. to 5.5	Pale yellow to orange-yellow	Radiated masses showing concentric banding	**Natrolite**	248
5. to 5.5	Greenish-yellow	Twin crystals, often gemmy	**Titanite**	204
5. to 6.	Cream-yellow	Separable into flexible fibers	**Amphibole-Asbestus**	216
5. to 6.	Lemon-yellow to orange	Associated with blue sodalite in nephelite-syenite	**Cancrinite**	225
5.5	Greenish or lemon-yellow, many shades	Fluorescence green under ultra-violet rays	**Willemite**	211
5.5 to 6.5	Many shades	Amorphous, brittle	**Opal**	240

Color Red:

2.5 to 5.5	Brownish-red, dull	Massive, oily luster to dull	**Serpentine**	242
4. to 5.	Flesh-red	Crystals are rhombs	**Chabazite, "Acadialite"**	247
4.5 to 5.	Rose-pink	In tetragonal crystals (figures 40 and 252)	**Apophyllite**	250
5.5 to 6.5	Brownish-red and other shades	Amorphous, brittle	**Opal**	240

Hardness	Color	Other Characteristics	Mineral	Page
5.5 to 6.5	Rose-pink	Triclinic crystals, or granular massive; tough	**Rhodonite**	190

Color Brown:

Hardness	Color	Other Characteristics	Mineral	Page
4.5 to 5.	Rusty-brown	Massive ore, often with druses of colorless crystals	**Calamine**	209
5.	Rusty-brown	Massive or mammillary	**Smithsonite**	209
5. to 5.5	Dark to blackish-brown	Streak yellowish-brown; never crystallized	**Limonite**	181
5. to 5.5	Dark to blackish-brown	Fibrous masses; same streak as limonite	**Goethite**	182
5. to 5.5	Blackish- and other shades of brown	Often in flat, monoclinic crystals; good cleavage	**Titanite**	204
5.5	Reddish-brown	Large coarse crystals, also massive; with franklinite	**Willemite**	211
5. to 6.	Reddish-brown	Bladed masses and crystals	**Pyroxene**	217
5. to 6.	Reddish-brown	Bladed masses and crystals	**Amphibole**	215
5.5 to 6.5	Various shades	Amorphous; brittle	**Opal**	240

Color Black or Gray:

Hardness	Color	Other Characteristics	Mineral	Page
4.5 to 5.	Light gray	Groups of crystals (see figures 40 and 252)	**Apophyllite**	250
5.	Light to dark gray	Mammillary masses	**Smithsonite**	209
5.	Light gray	Compact, or radiated	**Pectolite**	249
5. to 5.5	Black	Cleaves in one direction; G. 7.5; black streak; luster submetallic	**Wolframite**	205
5. to 5.5	Dark brown to black	Often in flat monoclinic crystals; good cleavage	**Titanite**	204
5.5	Black or gray	Masses of greasy luster: G. 4.1	**Willemite**	211

Hardness	Color	Other Characteristics	Mineral	Page
5.5	Black	Massive or botryoidal, rarely in isometric crystals; sub-metallic luster; very heavy, G. 9.	**Uraninite**	206
5. to 6.	Grayish- or brownish-black	Streak brownish-black, lustrous; massive or mammillary	**Psilomelane**	189
5. to 6.	Dull gray	Cleavable masses, often showing gorgeous change of colors	**Labradorite**	223
5. to 6.	Black or greenish-black or gray	Cleavage-angle 124½° (page 214); prismatic crystals, or bladed	**Amphibole**	216
5. to 6.	Black or greenish-black or gray	Cleavage-angle 93° (page 214); frequently shows basal parting (figure 228)	**Pyroxene**	218
5.5 to 6.	Gray	Trapezohedral crystals, figure 233. In lavas	**Leucite**	225
5.5 to 6.	Gray	Greasy luster; usually massive; crystals hexagonal	**Nephelite**	224
5.5 to 6.5	Gray or black	Amorphous; brittle	**Opal**	240

Color White, or Colorless:

Hardness	Color	Other Characteristics	Mineral	Page
4. to 5.	Colorless or white	Crystals are rhombs	**Chabazite**	247
4.5 to 5.	Colorless or white	Groups of crystals (see figures 40 and 252)	**Apophyllite**	250
4.5 to 5.	Colorless or white of various tints	Crystals usually in odd cockscomb groups, often drusy in cavities	**Calamine**	209
4.5 to 5.	White, either milky or of various shades	Double four-sided pyramidal crystals or masses	**Scheelite**	295
4. to 7.25	Yellowish- to snow-white	Coarsely-bladed	**Kyanite**	134
5.	White of various shades	Mammillary masses or crystals	**Smithsonite**	209
5.	Grayish- or yellowish-white to snow-white	Compact or radiated	**Pectolite**	249
5. to 5.5	Greenish- or yellowish-white	Usually in groups of crystals	**Datolite**	250

Hardness	Color	Other Characteristics	Mineral	Page
5. to 5.5	Colorless or white	Usually in trapezohedrons (figure 33), harder than most zeolites	**Analcite**	248
5. to 5.5	Colorless or white	Often in slender radiating crystals or radiating masses	**Natrolite**	248
5. to 5.5	Colorless or white	Much resembles natrolite, but acts differently when heated (see page 249)	**Scolecite**	248
5.5	Colorless, or various shades of white	Fluoresces (and sometimes phosphoresces) under ultra-violet rays	**Willemite**	211
5. to 6.	Snow-white, grayish-, yellowish-white	Bladed crystals or masses	**Amphibole, Tremolite**	215
5. to 6.	Colorless	Cleavable masses	**Labradorite (Utah)**	223
5.5 to 6.	Colorless or white	Trapezohedral crystals, figure 233. In lavas	**Leucite**	225
5.5 to 6.	Colorless or grayish-white	Hexagonal crystals with vitreous luster when transparent, but greasy if not clear	**Nephelite**	224
5.5 to 6.	Colorless	Usually in dodecahedrons, figure 28; vitreous luster	**Sodalite**	224
5.5 to 6.5	Colorless	Transparent, often encrusting, or in spherical forms, figure 129	**Opal, Hyalite**	241
5.5 to 6.5	Milk-white	Semi-translucent to opaque, amorphous, brittle	**Opal, Milk-opal**	241

Color Green or Blue:

2.5 to 5.5	Leek-, or blackish-green	Massive, oily luster	**Serpentine**	242
4.5 to 5.	Pale blue or green tints in white	Crystals usually in odd cockscomb groups, often drusy in cavities	**Calamine**	209
4. to 7.25	Sapphire-blue to green of many shades	Coarsely-bladed, or in elongated crystals	**Kyanite**	134

Hardness	Color	Other Characteristics	Mineral	Page
5.	Various shades of green or blue	Mammillary masses	**Smithsonite**	209
5.	Bluish- emerald-green	Crystals or masses have characteristic gorgeous color	**Dioptase**	173
5. to 5.5	Whitish-green	Usually in groups of crystals, with zeolites	**Datolite**	250
5. to 5.5	Deep blue of azure and other shades	Masses, usually called lapis lazuli, have many other minerals associated	**Lazurite**	225
5. to 5.5	Yellowish-green	Twin crystals, often gemmy	**Titanite**	204
5.5	Apple-green and many other shades	Fluoresces under ultra-violet rays	**Willemite**	211
5. to 6.	Yellowish-, grayish- and blackish-green	Cleavage angle 93° (page 214); frequently shows basal parting (figure 228)	**Pyroxene**	217
5. to 6.	Yellowish-, grayish- and blackish-green	Cleavage angle 124½° (page 214); often bladed	**Amphibole**	215
5. to 6.	Lilac or lavender	Bladed aggregates	**Amphibole, Hexagonite**	215
5.5 to 6.	Dark azure-blue	Frequently occurs in nephelite-syenite, sometimes with cancrinite	**Sodalite**	224
5.5 to 6.5	Apple-green	Like chrysoprase in color, but amorphous, with smooth fracture	**Opal, Prasopal**	240

(f) Hardness 6. to 6.75:
Color Yellow:

Hardness	Color	Other Characteristics	Mineral	Page
5. to 6.	Lemon-yellow to orange	Associated with blue sodalite in nephelite-syenite	**Cancrinite**	225
5.5 to 6.5	Many shades	Amorphous; brittle	**Opal**	240
6. to 6.5	Cream-yellow and other shades	Cleavage easy in two directions (figure 111) practically at right-angles	**Common feldspar, Orthoclase, Microcline**	221

Hardness	Color	Other Characteristics	Mineral	Page
6. to 7.	Brownish-yellow	Very heavy, G. 7; luster adamantine in crystals (often repeated twins), dull in masses	**Cassiterite**	201
6.5 to 7.	Pale honey-yellow	Transparent crystals; or fragments due to parting	**Spodumene**	186
6.5 to 7.5	Honey-yellow and many other shades	Common in dodecahedrons	**Garnet. Topazolite**	228

Color Red:

Hardness	Color	Other Characteristics	Mineral	Page
5.5 to 6.5	Brownish-red and other shades	Amorphous; brittle	**Opal**	240
5.5 to 6.5	Rose-pink	Triclinic crystals, or granular-massive; tough	**Rhodonite**	190
6. to 6.5	Flesh- to brick-red	Cleavage easy in two directions (figure 111) practically at right angles	**Common feldspar, Orthoclase, Microcline**	221
6. to 7.	Brick-red	Often shows striations and gorgeous schiller (page 116)	**Oligoclase, Sunstone**	224
6. to 6.5	Pinkish-brick-red	Lamellar masses	**Anorthite**	223
6. to 7.	Brownish- to ruby-red	Very heavy, G. 7; luster adamantine in crystals (often repeated twins), dull in masses	**Cassiterite**	201
6. to 6.5	Brownish- to blackish-red	Streak light brown; luster metallic-adamantine; crystals tetragonal-prismatic, sometimes capillary	**Rutile**	202
6.5 to 7.5	Ruby-, hyacinth-red, pink	Isometric crystals (figures 35, 234–236), also pebbles	**Garnet**	225

Color Brown:

Hardness	Color	Other Characteristics	Mineral	Page
5. to 6.	Reddish-brown	Bladed masses and crystals; cleavage angle 124½°	**Amphibole**	215

Hardness	Color	Other Characteristics	Mineral	Page
5. to 6.	Reddish-brown	Bladed masses and crystals; cleavage angle 93°	**Pyroxene**	217
5.5 to 6.5	Various shades	Amorphous; brittle	**Opal**	240
6. to 6.5	Hair-brown, reddish-brown	Streak light brown; luster metallic-adamantine; crystals tetragonal-prismatic, sometimes capillary	**Rutile**	202
6. to 7.	Various dark shades	Very heavy, G. 7; luster adamantine in crystals (often repeated twins), dull in masses	**Cassiterite**	201
6. to 7.	Dull brown	Fibrous or columnar masses	**Sillimanite**	135
6.5 to 7.	Reddish-brown	Granular masses, or small crystals. In volcanic rocks	**Chrysolite**	231
6.5 to 7.5	Various shades	Isometric crystals (figures 35, 234–236)	**Garnet**	225

Color Black or Gray:

5. to 6.	Grayish- or brownish-black	Streak brownish-black, lustrous; massive or mammillary	**Psilomelane**	189
5. to 6.	Black or greenish-black or gray	Cleavage angle 93° (page 214); frequently shows basal parting (figure 228)	**Pyroxene**	218
5. to 6.	Black or greenish-black or gray	Cleavage angle 124½° (page 214); prismatic crystals, or bladed	**Amphibole**	216
5.5 to 6.	Gray	Greasy luster; usually massive; crystals hexagonal	**Nephelite**	224
5.5 to 6.5	Gray or black	Amorphous; brittle	**Opal**	240
5. to 6.	Dull gray	Cleavable masses; often showing gorgeous change of colors	**Labradorite**	223
6. to 6.5	Gray	Cleavage easy in two directions (figure 111) practically at right angles	**Common feldspar, Orthoclase, Microcline**	221

Hardness	Color	Other Characteristics	Mineral	Page
6. to 7.	Black, greenish- to brownish-black	Lustrous crystals; green or brown by transmitted light	**Epidote**	219
6. to 7.	Various shades of gray or black	Very heavy, G. 7; luster adamantine in crystals (often repeated twins), dull in masses	**Cassiterite**	201
6.5 to 7.5	Coal-black	Isometric crystals (figures 35, 234–236)	**Garnet, Melanite**	228

Color White, or Colorless:

4. to 7.25	Yellowish- to snow-white	Coarsely-bladed	**Kyanite**	134
5. to 6.	Grayish-, greenish-, or yellowish-white	Bladed crystals, or masses	**Amphibole, Tremolite, Actinolite**	215, 216
5. to 6.	Grayish-, greenish-, or yellowish-white	Prismatic crystals, or masses	**Pyroxene, Diopside**	217
5.5 to 6.	Colorless or white	Trapezohedral crystals, figure 233. In lavas	**Leucite**	225
5.5 to 6.	Colorless or grayish-white	Hexagonal crystals with vitreous luster when transparent, but greasy if not clear	**Nephelite**	224
5.5 to 6.	Colorless	Usually in dodecahedrons, figure 28; vitreous luster	**Sodalite**	224
5.5 to 6.5	Colorless	Transparent; often encrusting, or in spherical forms, figure 129	**Opal, Hyalite**	241
5.5 to 6.5	Milk-white	Semi-translucent to opaque; amorphous; brittle	**Opal, Milk-opal**	241
6.	White of various shades	Readily cleavable; fuses easily (feldspar does not)	**Amblygonite**	186
5. to 6.	Colorless	Cleavable masses	**Labradorite (Utah)**	223
6. to 6.5	Colorless or white of various shades	Usually in tabular crystals or cleavages, often deeply striated; also lamellar	**Albite**	223

Hardness	Color	Other Characteristics	Mineral	Page
6. to 6.5	Colorless or white of various shades	Usually in stout crystals (tabular in sanidine), not striated, or masses with easy cleavage at right angles	**Common feldspar, Orthoclase, Microcline**	221
6. to 6.5	Colorless, glassy	In stout crystals (coated in Japan with lava)	**Anorthite**	223
6. to 7.	Colorless or white of various shades	Rarely in crystals, usually in striated cleavages	**Oligoclase**	224
6. to 6.5	Colorless, greenish- or yellowish-white	Barrel-shaped or globular groups of crystals, or in crystalline coatings	**Prehnite**	251
6. to 7.	Grayish-, brownish-, or yellowish-white	Fibrous or columnar masses	**Sillimanite**	135
6.5 to 7.	White of various shades, rarely colorless	In large, rough crystals, or fragments due to parting; also small, colorless, gem crystals	**Spodumene**	186
6.5 to 7.5	White, usually yellowish	Isometric crystals (figures 35, 234–236)	**Garnet, Grossularite**	226

Color Green or Blue:

4. to 7.25	Sapphire-blue to green of many shades	Coarsely-bladed, or in elongated crystals	**Kyanite**	134
5. to 6.	Yellowish-, grayish- and blackish-green	Cleavage angle 124½° (page 214); often bladed	**Amphibole**	215
5. to 6.	Lilac or lavender	Bladed aggregates	**Amphibole, Hexagonite**	215
5. to 6.	Yellowish-, grayish- and blackish-green	Cleavage angle 93° (page 214); frequently shows basal parting (figure 228)	**Pyroxene**	217
5.5 to 6.	Dark azure-blue	Frequently occurs in nephelite-syenite, sometimes with cancrinite	**Sodalite**	224
5.5 to 6.5	Apple-green	Like chrysoprase in color, but amorphous, with smooth fracture	**Opal, Prasopal**	240
6.	Robin's-egg-blue to grayish-green	Massive, in thin seams or scattered through rock	**Turquois**	136

Hardness	Color	Other Characteristics	Mineral	Page
6. to 6.5	Pale apple-green	Barrel-shaped or globular groups of crystals, or in crystalline coatings	**Prehnite**	251
6. to 6.5	Light green or bluish-green	In right-angle cleavages or stout crystals	**Microcline, Amazonstone**	222
6. to 7.	Yellowish-green (pistachio) to brownish-green	Usually in masses, with feldspar and quartz (unakite)	**Epidote**	219
6.5 to 7.	Yellowish- or olive-green	Granular masses, or small crystals. In volcanic rocks	**Chrysolite**	231
6.5 to 7.	Lilac or amethystine	Gem crystals, often showing etching	**Spodumene, Kunzite**	187
6.5 to 7.5	Emerald-green or yellowish-green	Isometric crystals (figures 35, 234–236) or gem pebbles	**Garnet, Uvarovite, Demantoid**	228, 228

(g) Hardness 7. to 10:
Color Yellow:

Hardness	Color	Other Characteristics	Mineral	Page
6. to 7.	Brownish-yellow	Very heavy, G. 7; luster adamantine in crystals (often repeated twins); dull in masses	**Cassiterite**	201
6.5 to 7.	Greenish-yellow	Granular masses or small crystals. In volcanic rocks	**Chrysolite**	231
6.5 to 7.	Pale honey-yellow	Transparent crystals, or fragments due to parting	**Spodumene**	186
6.5 to 7.5	Honey-yellow	In dodecahedrons (figure 234)	**Garnet, Topazolite**	228
7.	Honey-yellow	Transparent. No cleavage	**Quartz, Citrine**	234
7.	Ocher-yellow	Semi-translucent; rather granular masses	**Quartz, ferruginous**	235
7.	Ocher-yellow	Opaque; rather compact masses	**Quartz, Jasper**	239
7. to 7.5	Wine-yellow to brownish- and greenish-yellow	Transparent crystals, usually 3-, 6-, or 9-sided prisms	**Tourmaline**	244
7.5 to 8.	Pale, golden- and orange-yellow	In six-sided prisms, or masses; transparent to translucent	**Beryl, Golden Beryl**	142

Hardness	Color	Other Characteristics	Mineral	Page
8.	Wine-yellow	Transparent, prismatic crystals	**Topaz**	132
8.5	Greenish-yellow	Transparent, prismatic crystals, or pebbles. Rare	**Chryso-beryl**	135
9.	Honey-yellow	Transparent, often barrel-shaped crystals, or pebbles	**Corundum Sapphire**	131
10.	Canary-yellow	Transparent, isometric crystals	**Diamond**	156

Color Red:

Hardness	Color	Other Characteristics	Mineral	Page
6. to 7.	Brownish- to ruby-red	Very heavy, G. 7; luster adamantine in crystals (often repeated twins), dull in masses	**Cassiterite**	201
6. to 7.	Brick-red	Often shows striations and gorgeous schiller (page 116)	**Oligoclase, Sunstone**	224
6.5 to 7.5	Ruby-, hyacinth-red, pink	Isometric crystals (figures 35, 234–236); also pebbles	**Garnet**	225
7.	Rose-pink	Transparent or translucent masses	**Quartz, Rose Quartz**	234
7.	Brick-red	Translucent (rarely transparent) masses; often botryoidal; compact texture	**Quartz, Chalcedony**	236
7.	Brownish-red	Translucent to semi-translucent; compact texture	**Quartz, Carnelian**	236
7.	Brownish-red	Semi-translucent; rather granular masses	**Quartz, ferruginous**	235
7.	Many shades, mostly brownish-red	Opaque; rather compact masses	**Quartz, Jasper**	239
7. to 7.5	Rose-pink, ruby, violet-pink and other shades	Transparent or semi-translucent crystals, usually 3-, 6-, or 9-sided prisms	**Tourmaline, Rubellite**	244
7.5	Brownish-red, hyacinth-red	Transparent, tetragonal crystals, or pebbles, yielding fine gems; luster adamantine; G. 4.7	**Zircon**	212

Hardness	Color	Other Characteristics	Mineral	Page
7.5	Grayish- to rose-red	Rough, nearly square-prisms	**Andalusite**	134
7.5 to 8.	Pale rose-pink	Hexagonal-prismatic crystals; transparent to semi-translucent	**Beryl, Morganite**	142
8.	Brownish-rose-pink	Transparent; prismatic crystals	**Topaz**	132
9.	Deep, rich pigeon's-blood-red	Transparent or translucent; six-sided, often barrel-shaped crystals, also pebbles	**Corundum, Ruby**	131
9.	Rose-pink and other shades than pigeon's-blood-red	Often in large cleavable masses, as in smaragdite	**Corundum, pink sapphire**	131

Color Brown:

Hardness	Color	Other Characteristics	Mineral	Page
6. to 7.	Dark or light brown	Very heavy, G. 7; luster adamantine in crystals (often repeated twins); dull in pebbles or masses	**Cassiterite**	201
6. to 7.	Dull brown	Fibrous or columnar masses	**Sillimanite**	135
6.5 to 7.	Reddish-brown	Granular masses or small crystals. In volcanic rocks	**Chrysolite**	231
6.5 to 7.5	Various shades	Isometric crystals (figures 35, 234–236)	**Garnet**	225
7.	Yellowish- to smoke-brown	Transparent to sub-translucent; crystals or masses; no cleavage	**Quartz, Smoky quartz**	234
7.	Light to dark brown	Translucent (rarely transparent) masses; often botryoidal; compact texture	**Quartz, Chalcedony**	236
7.	Various shades	Opaque; rather compact masses	**Quartz, Jasper**	239
7. to 7.5	Dark brown	Often in cross twins. Figures 99–101	**Staurolite**	243
7. to 7.5	Mostly dark brown	Transparent to semi-translucent crystals, usually 3-, 6-, or 9-sided prisms	**Tourmaline**	244

Hardness	Color	Other Characteristics	Mineral	Page
7.5	Reddish- or smoke-brown	Transparent; tetragonal crystals, or pebbles; gemmy; luster adamantine; G. 4.7	**Zircon**	212
7.5 to 8.	Yellowish-brown	In six-sided prisms or masses; transparent to translucent	**Beryl**	142
9.	Light to dark brown	Often in large masses showing parting into rhombs	**Corundum**	131
10.	Light to dark brown	Isometric crystals; transparent to semi-translucent. A common type	**Diamond**	156

Color Black or Gray:

Hardness	Color	Other Characteristics	Mineral	Page
6. to 7.	Black or gray	Very heavy, G. 7; luster adamantine in crystals (often repeated twins); dull in pebbles and masses	**Cassiterite**	201
6. to 7.	Black, greenish- to brownish-black	Lustrous crystals; green or brown by transmitted light	**Epidote**	219
6.5 to 7.5	Coal-black	Isometric crystals (figures 35, 234–236)	**Garnet, Melanite**	228
7.	Light gray	Fibrous-granular masses	**Dumortierite**	135
7.	Brownish- to coal-black	Transparent to nearly opaque crystals or masses; no cleavage	**Quartz, Smoky quartz**	234
7.	Black or gray	Translucent (rarely transparent) masses; often botryoidal; compact texture	**Quartz, Chalcedony**	236
7.	Dull-black, smoky-black	Semi-translucent, slightly glistening; very tough, breaking with sharp edges	**Quartz, Flint**	238
7.	Dull black	Like flint, but more brittle and splintery	**Quartz, Chert**	238
7. to 7.5	Velvet-black	Opaque; prismatic crystals or columnar masses; no cleavage (unlike black hornblende)	**Tourmaline**	244

Hardness	Color	Other Characteristics	Mineral	Page
7.5	Light gray	Rough, prismatic crystals (often with carbonaceous inclusions, figure 161)	**Andalusite**	134
7.5	Gray or brownish-gray	Tetragonal crystals, figures 216–218; adamantine luster	**Zircon**	212
7. to 9.	Black or grayish-black	Heavy; granular masses	**Corundum, Emery**	131
9.	Various shades of gray to black	Often in large masses, granular, or showing parting; sometimes in hexagonal crystals; opaque or nearly so	**Corundum**	131
10.	Gray	Inferior crystals and masses full of flaws and feathers or impurities	**Diamond, Bort**	161
10.	Black	Apparently amorphous; hardest substance known	**Diamond, Carbon**	157

Color White, or Colorless:

Hardness	Color	Other Characteristics	Mineral	Page
4. to 7.25	Yellowish- to snow-white	Coarsely-bladed	**Kyanite**	134
6. to 7.	Grayish- or brownish-white	Fibrous or columnar masses	**Sillimanite**	135
6. to 7.	Colorless, snow-white or grayish-white	Transparent masses, rarely in crystals; usually in white, cleavable masses; more or less striated	**Oligoclase**	224
6.5 to 7.	White of various shades, rarely colorless	In large rough crystals, or fragments due to parting, also small, colorless gem crystals	**Spodumene**	186
6.5 to 7.5	White, usually yellowish	Isometric crystals, figures 35, 234–236	**Garnet, Grossularite**	226
7.	Colorless	Transparent, prismatic crystals of many types or clear masses; no cleavage	**Quartz, Rock crystal**	233
7.	Milk- to snow-white	Usually in large veins, sometimes in crystals, figure 244	**Quartz, Milky quartz**	234

Hardness	Color	Other Characteristics	Mineral	Page
7.	Snow-white to grayish	Semi-translucent, breaking like flint, but more splintery	Quartz, Chert	238
7.5 to 8.	Snow-white and other shades	Rough masses of great hardness distinguished from topaz by lack of distinct cleavage	Beryl	142
7.5 to 8.	Colorless or white of various tints	In six-sided prisms; transparent to semi-translucent	Beryl	142
8.	Colorless or white of various tints	In orthorhombic prisms, figures 158–160; transparent: also rough masses showing the reflection of light from innumerable cleavage faces	Topaz	132
9.	Colorless or white of various tints	Transparent, often barrel-shaped crystals, or pebbles; or large, nearly opaque masses, either granular or showing parting	Corundum	131
10.	Colorless or slightly tinted	Isometric crystals, transparent or translucent	Diamond	156

Color Green or Blue:

4. to 7.25	Sapphire-blue to green of many shades	Coarsely-bladed, or in elongated crystals	Kyanite	134
6. to 7.	Yellowish-green (pistachio) to brownish-green	Usually in masses, with feldspar and quartz (unakite)	Epidote	219
6.5 to 7.	Yellowish or olive-green	Granular masses, or small crystals. In volcanic rocks	Chrysolite	231
6.5 to 7.	Lilac or amethystine	Gem crystals, often showing etching	Spodumene, Kunzite	187
6.5 to 7.	Yellowish- to emerald-green	Small, deeply-etched crystals, yielding superb gems	Spodumene, Hiddenite	186
7.	Sapphire-blue or lavender	Fibrous-granular masses	Dumortierite	135

Hardness	Color	Other Characteristics	Mineral	Page
7.	Purple	Transparent crystals or semi-transparent masses; no cleavage	**Quartz, Amethyst**	234
7.	Pale blue	Translucent (rarely transparent) masses; often botryoidal; compact texture	**Quartz, Chalcedony**	236
7.	Apple-green	Translucent to semi-translucent masses; compact	**Quartz, Chrysoprase**	237
7.	Grayish-green	Nearly opaque, with red spots	**Quartz, Bloodstone**	238
7.	Various shades of green	Opaque, massive; rather compact	**Quartz, Jasper**	239
6.5 to 7.5	Emerald-green or yellowish-green	Isometric crystals (figures 35, 234–236), or gem pebbles	**Garnet, Uvarovite, Demantoid**	228 228
7. to 7.5	Various shades of green	Transparent to semi-translucent crystals, usually 3-, 6-, or 9-sided prisms	**Tourmaline**	244
7. to 7.5	Dark, blackish-blue	Transparent to semi-translucent crystals, usually 3-, 6-, or 9-sided prisms	**Tourmaline, Indicolite**	244
7.5	Green or blue of various shades	Transparent, gem crystals or pebbles; adamantine luster; heavy, G. 4.7	**Zircon**	212
7.5 to 8.	Emerald-green	Transparent to semi-translucent, six-sided prisms or masses	**Beryl, Emerald**	142
7.5 to 8.	Sea-green or blue	Transparent to semi-translucent, six-sided prisms or masses	**Beryl, Aquamarine**	142
8.	Colorless crystals tinted pale green or blue	In orthorhombic prisms, figures 158–160; good basal cleavage	**Topaz**	132
8.5	Deep grayish- to nearly emerald-green	Crystals are repeated twins, figure 163; columbine-red by artificial light	**Chrysoberyl, Alexandrite**	136

Hardness	Color	Other Characteristics	Mineral	Page
9.	Various shades of green and blue	Transparent, hexagonal prisms or barrel-shaped crystals; also rolled pebbles; yielding fine gems	**Corundum, Sapphire**	131
9.	Various shades of green and blue	Translucent to nearly opaque masses, showing parting	**Corundum, Sapphire**	131
10.	Various shades of green and blue	Transparent, isometric crystals, yielding fine gems. Very rare	**Diamond**	156

APPENDIX II

GUIDE TO PRONUNCIATION OF MINERAL AND ROCK NAMES

Much difference of opinion exists as to how certain mineral names should be pronounced. In preparing the following list of names used in this book, the pronunciations given almost invariably are taken from the Century Dictionary, the mineralogical portion of which was written by Professor E. S. Dana. If some of the items are at variance with your ideas, as they have been with the author's, if the reasons for the choice are weighed, it is probable that nearly all of them will prove acceptable.

KEY TO PRONUNCIATION

a as in fat
ā as in fate
ä as in far
â as in fall
ȧ as in ask
ã as in fare
e as in met
ē as in mete
ė as in her
i as in it
ī as in pine
o as in not
ō as in note
ö as in move
ô as in off
u as in tub
ū as in mute
u̇ as in pull
ü German ü
oi as in oil
ou as in pound

A single dot under a vowel in an unaccented syllable indicates its abbreviation and lightening, without absolute loss of its distinctive quality.

ạ̄ as in captain
ẹ̄ as in episcopal
ọ̄ as in democrat
ụ̄ as in singular

A double dot under a vowel in an unaccented syllable indicates that, even in the mouths of the best speakers, its sound is variable to, and in ordinary utterance actually becomes, the short *u*-sound (of but, pun, etc.).

a̤ as in errant
e̤ as in prudent
o̤ as in valor
ä̤ as in Persia
ṳ̄ as in feature
t̤ as in adventure

′ denotes primary, ″ a secondary accent
(A secondary accent is not marked if at its regular interval of two syllables from the primary, or from another secondary.)

PRONOUNCING VOCABULARY

A

Acadialite—a-kā'di-a̤l-īt
Actinolite—ak-tin'o̤-līt
Alabaster—al'a̤-bȧs-tėr
Albite—al'bīt
Alexandrite—al-eg-zan'drīt
Almandine—al'ma̤n-din
Almandite—al'ma̤n-dīt
Alunite—al'ṳ̄-nīt
Amblygonite—am-blig'o̤-nīt
Amethyst—am'ḙ-thist
Amphibole—am'fi-bōl
Amphibolite—am-fib'o̤-līt
Analcite—a-nal'sīt
Andalusite—an-da̤-lū'sīt
Andesine—an'dḙ̄-zin
Andesite—an'dḙ̄-zit
Andradite—an'dra̤-dīt
Anglesite—ang'gle-sīt
Anhydrite—an-hī'drīt
Anorthite—an-ôr'thīt
Anorthoclase—an-ôr'thō-klāz
Anorthosite—an-ôr'thō-sīt
Anthracite—an'thra̤-sīt
Antimony—an'ti-mō̤-ni
Apatite—ap'a̤-tīt
Aphrosiderite—af-rō̤-sid'e̤-rīt
Apophyllite—a̤-pof'i-līt
Aragonite—ar'a̤-go̤-nīt
Argentite—är'je̤n-tīt
Arsenic—är'se-nik
Arsenopyrite—är″se-nō-pī'rīt
Asbestos—as-bes'to̤s
Asbestus—as-bes'tus
Asphaltum—as-fal'tum
Augite—â'jīt
Aurichalcite—â-ri-kal'sīt
Aventurine—a-ven'tṳ̄-rin
Axinite—ak'si-nīt
Azurite—azh'ṳ̄-rīt

B

Baddeleyite—bad'li-īt
Barite—bā'rīt
Basalt—ba̤-sâlt' or bas'âlt
Bauxite—bō'zīt
Bertrandite—bėr'tra̤nd-īt
Beryl—ber'il
Betafite—bā-täf'īt
Bindheimite—bind'hī-mīt
Biotite—bī'o̤-tīt
Blende—blend
Borax—bō-raks
Bornite—bôr'nīt
Bort—bôrt
Bortz—bôrtz
Bournonite—bör'no-nīt
Breccia—brech'ia̤
Bronzite—bron'zīt
Brookite—brůk'īt
Brucite—brȯ'sīt
Bytownite—bī'toun-īt

C

Cairngorm—cārn'gôrm
Calamine—kal'a-min
Calaverite—kal-a-vē'rīt
Calcareous tufa—kal-kā'rḙ̄-us tö'fa
Calcite—kal'sīt
Calc-tufa—kalk-tö'fa̤
Cancrinite—kang'kri-nīt
Carnallite—kär'na̤l-īt
Carnelian—kär-nē'lyan
Carnotite—kär'nō-tīt
Cassiterite—ka-sit'e̤-rīt
Celestite—sel'es-tīt

Cerargyrite—se-rär'ji-rīt
Cerussite—ser'ö-sīt
Cervantite—sėr-van'tīt
Chabazite—kab'ạ-zīt
Chalcedony—kal-sed'ō-ni
Chalcocite—kal'ko-sīt
Chalcopyrite—kal-ko-pī'rīt or kal-kop'i-rīt
Chalcotrichite—kal-kot'ri-kīt
Chert—chėrt
Chiastolite—kī-as'tọ-līt
Chlorite—klō'rīt
Chromite—krō'mīt
Chrysoberyl—kris'ọ-ber-il
Chrysocolla—kris-ọ-kol'ạ̈
Chrysolite—kris'ọ-līt
Chrysoprase—kris'ọ-prāz
Chrysotile—kris'ọ-til
Cinnabar—sin'ạ-bär
Citrine—sit'rin
Clinochlore—klī'nọ-klōr
Cobaltite—kō'bâl-tīt
Colemanite—kōl'mạn-īt
Collophanite—kol-lof'a-nīt
Conglomerate—kọn-glom'ẹ-rạt
Copalite—kō'pal-īt
Coquina—kọ-kē'nạ̈
Cortlandite—kôrt'land-īt
Corundum—kō-run'dum
Crocidolite—krọ-sid'ọ-līt
Crocoite—krō'kọ-īt
Cryolite—krī'ọ-līt
Cuprite—kū'prīt
Cyanite—kī'ạ-nīt

D

Dacite—dā'sīt
Datolite—dat'ọ-līt
Demantoid—de-man'toid
Dendrite—den'drīt
Descloizite—dā-cloi'zīt
Diabantite—dī-ạ-ban'tīt
Diabase—dī'ạ-bās
Diatomaceous earth—dī"ạ-tọ-mā'shius ėrth
Diatomite—dī-at'ọ-mīt
Diopside—dī-op'sīd
Dioptase—dī-op'tās
Diorite—dī'ọ-rīt
Dolerite—dol'ẹ-rīt
Dolomite—dol'ọ-mīt
Drusy quartz—drö'zi kwârts
Dumortierite—dụ-môr'tēr-īt
Dunite—dun'īt

E

Elaeolite—e-lē'ọ-līt
Electrum—ẹ̄-lek'trum
Embolite—em'bọ-līt
Emerald—em'ẹ-rạld
Enstatite—en'stạ̄-tīt
Epidote—ep'i-dōt
Erythrite—e-rith'rīt
Essonite—es'ọ-nīt

F

Feldspar—feld'spär
Felsite—fel'sīt
Ferberite—fėr'bėr-īt
Ferruginous quartz—fer-rö'ji-nus kwârts
Flos-ferri—flos-fer'ī
Fluorite—flö'ọ-rīt
Fowlerite—fou'lėr-īt
Franklinite—frangk'lin-īt
Fuchsite—fök'sīt

G

Gabbro—gab'rō
Gadolinite—gad'o-lin-īt
Galena—gạ-lē'nạ̈
Garnierite—gär'niėr-īt

Geode—jē'ōd
Geyserite—gī'sėr-īt
Gilsonite—gil'sọn-īt
Glauberite—glâ'bėr-īt
Glauconite—glâ'kọ-nīt
Gneiss—nīs
Goethite—gė'tīt
Graphite—graf'īt
Grossularite—gros'ū̦-lär-īt
Gummite—gum'īt
Gypsum—jip'sum

H

Halite—hal'īt or ha'līt
Heliotrope—hē'li-ọ-trōp
Hematite—hem'ạ-tīt
Hemimorphite—hem-i-môr'fīt
Heulandite—hū'lạn-dīt
Hexagonite—hek-sag'ọ-nīt
Hiddenite—hid'n-īt
Hornblende—hôrn'blend
Hornblendite—horn'blend-īt
Huebnerite—hüb'nėr-īt
Hyacinth—hī'ạ-sinth
Hyalite—hī'ạ-līt
Hydrolite—hī'drọ-līt
Hypersthene—hī'pėr-sthēn

I

Ilmenite—il'men-īt
Indicolite—in-dik'ọ-līt
Iodyrite—ī-od'i-rīt
Iridosmine—ir-i-dos'min
Iron pyrites—ī'ėrn pi-rī'tēz
Isinglass—ī'zing-glȧs

K

Kaolin—kā'ọ-lin
Kaolinite—kā'ọ-lin-īt
Kauri gum—kou'ri gum
Kernite—kėrn'īt
Kimberlite—kim'bėr-līt
Kunzite—könts'īt
Kyanite—kī'ạ-nīt

L

Labradorite—lab'rạ-dôr-īt
Långbanite—läng'ban-īt
Lapis lazuli—lā'pis (or lap'is) laz'ū̦-lī
Lazurite—laz'ū̦-rīt
Lepidolite—lep'i-dọ-līt
Leucite—lū'sīt
Lignite—lig'nīt
Limonite—lī'mọ-nīt
Lodestone—lōd'stōn

M

Magnesite—mag'nẹ-sīt
Magnetite—mag'ne-tīt
Malachite—mal'ạ-kīt
Manganite—mang'gạ-nīt
Marcasite—mär'kạ-sīt
Melanite—mel'ạ-nīt
Menaccanite—mẹ-nak'ạn-īt
Mesolite—mes'ọ-līt
Meteorite—mē'tẹ-ọr-īt
Mica—mī'kạ
Micaceous hematite—mī'kā-shius hem ạ-tīt

Mica-schist—mī-kā shist
Microcline—mī′krọ-klīn
Mimetite—mim′ẹ-tīt
Mirabilite—mī-rab′i-līt
Mispickel—mis′pik-el
Molybdenite—mō-lib′dē-nīt or mol-ib-de′nīt
Mundic—mun′dik
Muscovite—mus′kọ-vīt

N

Naphtha—naf′thạ̈ or nap′thạ̈
Natrolite—nat′rọ-līt
Nemalite—nem′ạ-līt
Nephelite—nef′e-līt
Niccolite—nik′ọ̈-līt

O

Obsidian—ọb-sid′i-ạn
Ocher—ō′kėr
Octahedrite—ok-tạ-hē′drīt
Oligoclase—ol′i-gọ-klās
Olivenite—ol′i-ve-nīt
Olivine—ol′i-vin
Onyx—on′iks
Oolite—ō′ọ-līt
Oolitic hematite—ō-ọ-lit′ik hem′ạ-tīt
Opal—ō′pạl
Orpiment—ôr′pi-mẹnt
Orthoclase—ôr′thọ-klāz
Ozocerite—ō-zọ-sē′rīt or ō-zọ-kē′rīt

P

Paraffin—par′ạ-fin
Patronite—pa-trō′nīt
Pectolite—pek′tọ-līt
Pegmatite—peg′mạ-tīt
Penninite—pen′i-nīt
Pentlandite—pent′lạnd-īt
Peridot—per′i-dot
Peridotite—per′i-dọ-tīt
Peristerite—pe-ris′tẹ-rīt
Petroleum—pẹ-trō′lē-um
Phenacite—fen′ạ-sīt
Phlogopite—flog′ọ-pīt
Phonolite—fō′nọ-līt
Phosphate—fos′fāt
Phosphorite—fos′fọ-rīt
Picrolite—pik′rọ-līt
Pisolite—pī′sọ-līt
Pitchblende—pich′blend
Pitchstone—pich′stōn
Plagioclase—plā′ji-ọ-klāz
Platinum—plat′i-num
Polyadelphite—pol″i-ạ-del′fīt
Polybasite—pọ-lib′ạ-sīt
Porphyry—por′fi-ri
Prehnite—pren′īt
Prochlorite—prọ-klō′rīt
Proustite—prös′tīt
Psilomelane—sī-lom′e-lān
Pumice—pum′is
Pyrargyrite—pī-rär′ji-rīt
Pyrite—pī′rīt
Pyrites—pi-rī′tēz
Pyrolusite—pī-rọ-lū′sīt
Pyromorphite—pī-rọ-môr′fīt
Pyrope—pī′rōp
Pyrophyllite—pī-rọ-fil′īt
Pyroxene—pī′rok-sēn
Pyroxenite—pī-rok′sen-īt
Pyrrhotite—pir′ọ-tīt

Q

Quartz—kwârts
Quartzite—kwârt′sīt

R

Realgar—rẹ-al'gạr
Rhodochrosite—rō-dọ-krō'sīt
Rhodonite—rō'dọ-nīt
Rhyolite—rī'ọ-līt
Roscoelite—ros'kọ-līt
Rosolite—rōz'ọ-līt
Rouge—rözh
Rubellite—rö'bel-īt
Rutilated quartz—rö'ti-lāt-ed kwârts
Rutile—rö'til

S

Sagenitic quartz—saj-e-nit'ik kwârts
Sapphire—saf'īr
Sassolite—sas'ọ-līt
Scheelite—shē'līt
Scolecite—skōl'ē-sīt
Selenite—sel'ẹ-nīt
Senarmontite—se-när'mọnt-īt
Serpentine—sėr'pẹn-tin
Siderite—sid'ẹ-rīt
Siliceous sinter—si-lish'us sin'tėr
Sillimanite—sil'i-mạn-īt
Smaltite—smâl'tīt
Smithsonite—smith'sọn-īt
Sodalite—sō'dạ-līt
Soda niter—sō'dạ nī'tėr
Spathic iron—spath'ik ī'ėrn
Sperrylite—sper'i-līt
Spessartite—spes'ạr-tīt
Sphalerite—sfal'ẹ-rīt
Spherosiderite—sfē-rọ-sid'ẹ-rīt
Spinel—spi-nel'
Spodumene—spod'ụ-mēn
Stalactite—stạ-lak'tīt
Stalagmite—stạ-lag'mīt
Stannite—stan'īt
Staurolite—stâ'rō-līt
Steatite—stē'ạ-tīt
Stephanite—stef'ạn-īt
Stibnite—stib'nīt
Stilbite—stil'bīt
Strontianite—stron'shi-ạn-īt
Sulphur—sul'fėr
Syenite—sī'e-nīt
Sylvanite—sil'vạn-īt
Sylvite—sil'vīt

T

Talc—talk
Tetrahedrite—tet-rạ-hē'drīt
Thenardite—thẹ-när'dīt
Thomsonite—tom'sọn-īt
Tincalconite—ting-kạl-kō'nīt
Titanite—tī'tạn-īt
Topaz—tō'paz
Topazolite—tọ-paz'ọ-līt
Tourmaline—tör'mạ-lin
Trachyte—trak'īt
Travertine—trav'er-tin
Tremolite—trem'ọ-līt
Trona—trō'nạ
Troostite—trös'tīt
Turquois—tėr'koiz or tėr-koiz

U

Uintahite—ū-in'tạ-hīt
Ulexite—ū'lek-sīt
Unakite—ū-nä'kīt
Uraninite—ụ-ran'i-nīt
Uranophane—ū-ran'o-fān
Uvarovite—ö-var'ọ-vīt

V

Valentinite—val'en-tin-īt
Vanadinite—vȧn-ȧd'in-īt
Verd-antique—vėrd-an-tēk'
Viluite—vil'ö-īt

W

Wernerite—wėr′nėr-īt
Willemite—wil′em-īt
Witherite—with′ėr-īt
Wolframite—wůl′fram-īt
Wulfenite—wůl′fen-īt
Wurtzilite—wėrt′zil-īt

Z

Zeolite—zē′ọ-līt
Zincite—zing′kīt
Zircon—zėr′kọn

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